THE UNIVERSITY OF ALBERTA

RELEASE FORM

NAME OF AUTHOR: Gary Kovacik

TITLE OF THESIS: Apparent Viscosity of Coal-Oil Slurries

DEGREE FOR WHICH THESIS WAS PRESENTED: M.Sc.

YEAR THIS DEGREE GRANTED: Spring, 1984.

THE UNIVERSITY OF ALBERTA

# APPARENT VISCOSITY OF COAL-OIL SLURRIES

by

© GARY KOVACIK

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF MECHANICAL ENGINEERING

EDMONTON, ALBERTA

SPRING, 1984

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommended to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "Apparent Viscosity of Coal-Oil Slurries" submitted by Gary Kovacik in partial fulfillment of the requirements for the degree of Master of Science in Mechanical Engineering.

## ABSTRACT


The viscosities of coal-anthracene oil and coal-bitumen slurries have been measured at atmospheric pressure, at temperatures up to 150°C, and with coal loadings up to 50% by weight. These measurements were performed using a Couette type Haake Rotoviscometer. The effects of varying shear rate, temperature, and coal concentration have been correlated with Newtonian and power law fluid models, an absolute rate theory, and the classical theories of suspended particle slurries, respectively.

The results obtained indicated that the slurries behaved as Newtonian fluids at lower coal concentrations. Increasing coal loadings caused an increasing non-Newtonian pseudoplastic behaviour of the slurries. The viscosity-temperature dependence may be modelled using the theory of absolute rates. The viscosity-coal concentration dependence may be correlated using classical theories of suspended particle slurries, but the effect of coal concentration on slurry viscosity was greater than that for slurries reported in the literature.

ACKNOWLEDGEMENTS

The author wishes to express his appreciation of the encouragement and guidance given by Dr. C.M. Rodkiewicz in the successful completion of this thesis.

The author gratefully acknowledges the Alberta/Canada Energy Resources Research Fund administered by Alberta Energy and Natural Resources and the Alberta Research Council whose financial assistance made this work possible.

The author is also grateful to Dr. Baki Ozum of the ARC Coal Department for his help and indefatigueable interest in this project. R. Chisotti's excellent drafting work was greatly appreciated. Miss B. Morgan must also be thanked for her excellent work in typing the manuscript.

TABLE OF CONTENTS

LIST OF TABLES

## LIST OF FIGURES

PAGE

## NOMENCLATURE

| | |
|---|---|
| A | system constant |
| a | a constant |
| B | system constant |
| b | a constant |
| $C_v$ | volume concentration |
| $C_w$ | weight concentration |
| c | a constant |
| D | shear rate |
| d | width of gap |
| $\frac{dv_\theta}{dr}$ | tangential shear rate |
| F* | standard free energy of Activation for Flow |
| $\Delta H$ | activation energy of viscosity |
| h | depth of immersion |
| h | Plank's constant |
| K | flow consistency index |
| K | Einstein Equation Constant |
| K1, K2 | constants |
| M | Torque |
| N | Avogadro's number |
| n | flow behaviour index |
| R | Universal gas constant |
| $R_i$ | inner cylinder radius |
| Ro | outer cylinder radius |
| r | radius |
| $r^2$ | correlation coefficient |
| T | temperature |

$V$ molar volume

$V_i$ peripheral velocity of inner cylinder

GREEK SYMBOLS

| | |
|---|---|
| $\phi$ | volume concentration |
| $\eta_{rel}$ | reduced viscosity |
| $\Omega, \omega$ | angular velocity |
| $\mu$ | viscosity |
| $\mu_a$ | apparent viscosity |
| $\mu_{eff}$ | effective viscosity |
| $\mu_o$ | viscosity of suspending fluid |
| $\rho$ | density |
| $\tau$, $\tau_{xy}$, $\tau_{R\theta}$ | shear stress |
| $\frac{\partial v_x}{\partial y}$, $\frac{\partial v_\theta}{\partial r}$ | shear rate |

# 1. INTRODUCTION

## 1.1 Objectives

The viscosity of coal slurries is one of the most important physical parameters required for the efficient design of coal liquefaction processes and equipment. The objective of this work was to quantify the viscosity of the two coal oil mixtures currently used in liquefaction research in Alberta. These slurries were mixtures of pulverized coal and anthracene oil, a product of coal coking process, and bitumen from Alberta's oil sands.

Three variables which affect slurry behaviour were investigated. These variables were shear rate, temperature, and coal concentration. The effects of these variables on slurry viscosity were to be quantified and then correlated with known models wherever possible. The ultimate goal of this work was to attempt to arrive at a correlation which would incorporate these variables and could be used to predict the viscosity of coal slurries made with these two solvents.

## 1.2 Viscosity Models and Measurements with a Couette Viscometer

In this work two models were used to correlate the shear rate to shear stress data produced by the instruments.

The first model used was the Newtonian fluid model:

$$\tau_{xy} = -\mu \left[ \frac{\partial v_x}{\partial y} + \frac{\partial v_y}{\partial x} \right] \tag{1.1}$$

Where:

$\tau_{xy}$ = shear stress, [Pa]

$\mu$ = absolute viscosity, [Pa.s]

$\frac{\partial v_x}{\partial y}$ = shear rate in y-direction, [$s^{-1}$]

$\frac{\partial v_y}{\partial x}$ = shear rate in x-direction, [$s^{-1}$]

Measurements in this study were performed using an instrument that was calibrated, assuming one dimensional, laminar, Newtonian Couette flow, see Figure 1.1 therefore equation (1.1) becomes, in cylindrical coordinates,

$$\tau_{r\theta} = \mu \left[ \frac{-dv_\theta}{dr} \right] \tag{1.2}$$

The other model used to correlate data was a two parameter power-law model, which is formulated as:

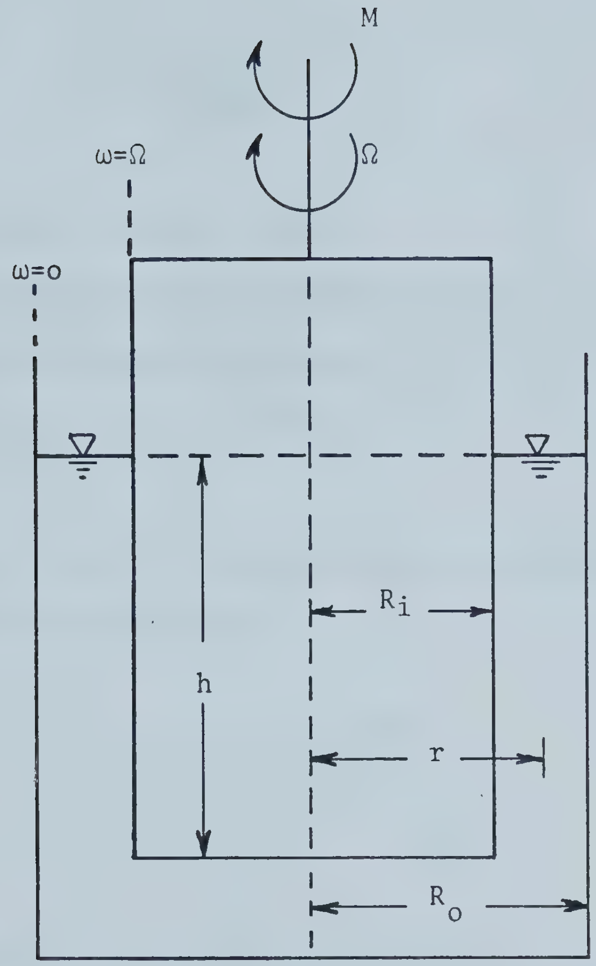



Figure 1.1 Couette Viscometer Configuration

$$\tau_{r\theta} = K \left| \frac{-dv_\theta}{dr} \right|^n \tag{1.3}$$

Where:

$\tau_{r\theta}$ = shear stress, [Pa.s]

K = flow consistency index, [Pa.s $^{1/n}$]

n = flow behaviour index

$\frac{dv_\theta}{dr}$ = shear rate, [$s^{-1}$]

From equation (1.3) a relationship describing an apparent viscosity can be developed:

$$\mu_a = K \left| \frac{-dv_\theta}{dr} \right|^{n-1} \tag{1.4}$$

Where:

$\mu_a$ = apparent viscosity, [Pa-s]

The apparent viscosity in equation (1.4) is similar to the Newtonian or absolute viscosity in that it is the ratio of shear stress to shear rate measured by the instrument.

For the instrument used in this study, see Figure 1.1, the physical quantitities which were measured were the torque, M, and the angular velocity, $\Omega$ , applied to the inner cylinder. Therefore, there must be some way to relate these measured quantities to the shear rate and shear stress developed in the fluid. These relations must

be found in order to determine the particular model parameters, (i.e. absolute viscosity, or flow consistency index and flow behaviour index, that will be required to classify the fluid).

For the steady, incompressible, one dimensional, laminar flow of a fluid in the instrument shown in Figure 1.1 for which one also assumes a no slip condition at the wall and that the end effects are negligible the shear stress at the inner cylinder can be calculated from a simple force balance.

Torque = Surface Area x Shear Stress x Radius

$$M = 2\Pi R_i h \times \tau_{r\theta}\Big|_{r=R_i} \times R_i \qquad (1.5)$$

Therefore, for any fluid staisfying the above assumptions the shear stress at the wall of the inner cylinder can easily be determined knowing the input torque, M, and the physical dimensions of the instrument.

For a Newtonian fluid an analytical solution of the Navier Stokes equations is possible for Couette flow [43]. From this solution it is possible to derive a function for the rate of shear across the gap between the two cylinders:

$$\frac{dv_\theta}{dr} = \frac{2\Omega}{r^2} \frac{R_i^2 R_o^2}{R_o^2 - R_i^2} \tag{1.6}$$

Where:

$\frac{dv_\theta}{dr}$ = shear rate, [$s^{-1}$]

$\Omega$ = angular speed of the inner cylinder, [rad/s]

$R_o$ = radius of outer cylinder, [m]

$R_i$ = radius of inner cylinder, [m]

$r$ = radius, [m]

At the inner cylinder equation (1.6) becomes:

$$\left.\frac{dv_\theta}{dr}\right|_{r=R_i} = 2\Omega \frac{R_o^2}{R_o^2 - R_i^2} \tag{1.7}$$

Thus, for a Newtonian fluid the shear rate at the inner cylinder can also be easily determined if the angular speed of inner cylinder, $\Omega$ , and the physical diminsions of the instrument are known. If the shear stress versus shear rate curve is plotted for a fluid that behaves as Newtonian the results should be a straight line of slope $\mu$, from equation (1.2).

For a general fluid of an unknown shear stress to shear rate behaviour an exact solution of the equations of motion is not possible, although fairly accurate approximations are available for large or small gaps

[11, 50]. If a power-law relationship is assumed between the shear stress and the shear rate the shear rate at the inner cylinder can also be determined from the solution of the equations of motion for a power-law fluid in Couette flow. For this geometry and a power law fluid it can be shown that [50 ]:

$$\Omega = \frac{n}{2} \sqrt[n]{\frac{\tau_{r\theta}\big|_{r=R_i}}{K}} \left[ 1 - \frac{R_i}{R_o}^{2/n} \right] \qquad (1.8)$$

Where:

$\tau_{r\theta}$ = shear stress at inner cylinder, [Pa]

K = flow consistency index

n = flow behaviour index

From equation (1.3) we know that at $r = R_i$

$$\tau_{r\theta}\Big|_{r=R_i} = K \left| \frac{-dv_\theta}{dr} \right|^n \Bigg|_{r=R_i} \qquad (1.9)$$

Substituting (1.9) into (1.8) and rearranging

$$\left. \frac{dv_\theta}{dr} \right|_{r=R_i} = \frac{2\Omega}{n} \frac{1}{\left[ 1 - \frac{(R_i)}{R_o}^{2/n} \right]} \qquad (1.10)$$

There is a major difficulty in employing equation (1.10), however. That is that the flow behaviour index, n, of the fluid, must be known before the shear rate can be calculated. This is impossible to do because the rheological measurements are being performed to determine

the values of the flow behaviour index and the flow consistency index, K, in order to correlate the measured data with equation (1.3). It should be noted that for n = 1.0 equation (1.10) is equivalent to equation (1.7). Therefore, what was done for the instrument used in this work was to calibrate the output of the shear rate scale which assumed Newtonian fluid behaviour. If the n values calculated from this data are near 1.0 the error in the shear rate can be neglected relative to the stated instrument measurement error of $\pm$ 5%.

The magnitude of the shear rate error in this study was approximated using the geometric dimensions of the viscometer, see Table 1.1, and the minimum value for the flow behaviour index calculated (see Table 2.1). Since this value for n was calculated assuming the Newtonian shear rate relationship equation (1.7), a slightly more conservative value for n of 0.80 was used to estimate the shear rate error.

Using equations (1.7) and (1.10), the geometric dimensions of the instrument, and assuming a minimum flow behaviour index of 0.8 the following results are found:

Newtonian Fluid Assumption

$$\left. \frac{dv_\theta}{dr} \right|_{r=R_i} = 8.61\ \Omega \qquad (1.11)$$

Power-Law Fluid Assumption, n = 0.80

$$\left. \frac{dv_\theta}{dr} \right|_{r=R_i} = 8.88\ \Omega \qquad (1.12)$$

Therefore, the maximum error in the shear rate values used in analysing the data in this study was -3.1%. This value was within the stated error limits of the instrument and can therefore be neglected when analysing the data.

Another possible source of measurement error that must be considered when using a Couette viscometer is a shear stress error arising from the assumption of negligible end effects not being satisfied. For this instrument end effects are minimized by the special design of the inner cylinder, see Figure 1.2. The sharp edges and recesses at the top and bottom help reduce the end effects by promoting a more 1-dimensional velocity field in the gap. The recess at the bottom also helps reduce the end effect by trapping an air bubble between the bottom of the cylinder and the fluid being measured. However, even with these precautions taken in the design of the viscometer an end effect correction factor must be applied to the shear stress scale of the output. Based on the physical dimensions of the inner and outer cylinders and applying the German Standard Din 53 018 for end effect corrections, a multiplying factor of 1.13 must be applied to the output shear stress scale.

The final aspect of Couette flow that must be considered for Couette type viscosity measurements was; were the assumptions pertaining to the velocity field satisfied? In other words, was the flow totally laminar or was secondary flow present in the annulus

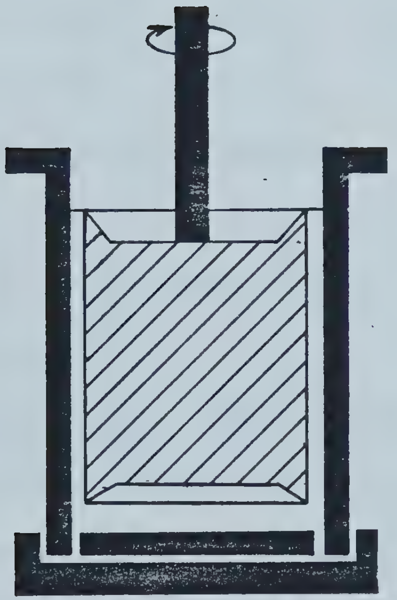


Figure 1.2 Special Design of Viscometer Inner Cylinder

between the two cylinders. From correlations developed by Taylor [43], the criterion that must be satisfied to insure the absense of secondary flow in a Couette viscometer is:

$$\frac{V_i \rho d}{\mu} \left(\frac{d}{R_i}\right)^{1/2} < 41.3 \qquad (1.13)$$

Where:

$V_i$ = peripheral velocity of the inner cylinder

$d$ = width of the gap

$R_i$ = inner radius

$\rho$ = fluid density

$\mu$ = absolute fluid viscosity

The assumption in this equation is that the fluid is Newtonian in nature.

In this study the lowest measured viscosity was present in the pure solvent (specifically anthracene oil) at the highest temperature measured (150°C). From the geometric dimensions of the viscometer used and assuming a conservative fluid density of 1.0 g/cm$^3$ the minimum viscosity required for insurance of laminar flow is found to be $\sim$10 cp by equation 1.13. The minimum apparent viscosity measured in this investigation was $\sim$5 cp.

Therefore secondary flow may have been on the verge of developing in the measurements of anthracene oil viscosity at approximately 150°C. Based on this it can be assumed that the effects of secondary flow would have a negligible effect on the data collected in this work.

An unfortunate consequence of the design of the particular viscometer used in this work was the inability to detect the presence or absense of a stress component normal to the direction of flow. Thus it was impossible to state whether or not a fluid displaying a typically Newtonian shear stress versus shear rate curve (linear) was conclusively a Newtonian fluid. Therefore, in the discussion that follows all viscosities calculated will be stated as "apparent viscosities" whether the shear stress versus shear rate curves are linear or not. Linear shear stress versus shear rate curves will be referred to as "Newtonian behaviour".

## 1.3 Slurry Viscosity Models - Survey of Theoretical Work

Theoretical work attempting to model the rheological properties of coal slurries, specifically, is non-existant. However, there has been extensive work done, with varying degrees of success, to theoretically describe the flow behaviour of suspensions of spherical particles in Newtonian fluids. The difficulity in deriving theoretical models which accurately account for the rheological behaviour of "real" slurries (eg. coal slurries, ore slurries, etc.) is that there is an almost endless number of parameters that must be accounted for. Some of these parameters are; solids concentration, particle size and size distribution, particle shape, chemical interaction, temperature effects, electrostatic effects, coagulation, etc. The parameters which will be discussed here are those which most affect the behaviour of coal slurries and those which at least to some extent, have been addressed in the literature. These are shear rate, temperature effects, and solids concentration.

### 1.3.1 Solids Concentration Effect

There has been considerable theoretical work performed in attempting to model the effect of concentration on the viscous properties of suspensions of

rigid particles. One of the several review papers concerning this topic which was quite extensive was by Jeffery and Acrivos (1976) [25]. Most of this work has been an attempt to extend an equation developed by Einstein (1956) which applies to spherical particles which are nearly infinitely diluted in a Newtonian fluid.

$$\mu_{eff} = \mu_o (1 + K\phi)$$

Where: (1.14)

$$\phi = \frac{\text{Volume of Partices}}{\text{Total Volume of Suspension}} \ll 1$$

$\mu_o$ = Viscosity of suspending fluid

$\mu_{eff}$ = Effective viscosity of suspension

K = 2.5 for very dilute systems.

There exists numerous empirical and theoretical extensions of Einstein's equation in the literature [4,13, 22, 27, 51, 55]. These extensions mainly include higher order terms of, $\phi$ , but, no matter how complicated these extensions become they do not accurately account for the inevitable non-Newtonian character of the suspension for

o>0.2. In fact only Thomas (1963), [48] even considered this problem. Shaheen (1971), [45] presented an empirical correlation for this non-Newtonian behaviour. Recently, [1], however, this problem was addressed theoretically, but experimental work is required to verify the result.

The effects of particle concentration can generally be described as follows:

1. Concentrated suspension ( $\phi > 0.2$) are generally shear thinning, except for concentrated suspensions of fine particles which may be dilatant.
2. The degree of non-Newtonian behaviour generally increases with concentration and with decreases in particle size. [28, 54].

### 1.3.2 Temperature Effect

The temperature dependence of viscosity has been modelled theoretically, with varying degrees of success by Eyring and co-workers [20]. This approximate theory was based on the absolute theory of rate processes. It involves a semi-empirical application of statistical mechanics to the kinetics of flow. Eyring considered a liquid to be an imperfect molecular lattice containing a number of vacant lattice sites called "holes". By considering diffusion and flow as rate processes, based on the motion of the molecules into the available sites or

holes, the following equation was derived for simple Newtonian fluids:

$$\mu = (Nh/V) \exp (\Delta F^*/RT)$$

Where: (1.15)

$\mu$ = viscosity

N = Avogadro's number

h = Plank's constant

V = molar volume

$\Delta F^*$ = Standard Free Energy of Activation for Flow per mole

R = Universal gas constant

T = Absolute Temperature

Equation (1.15) was not highly accurate, errors as much as 30 per cent are common. It is stated [6] to be theoretically applicable for hydrocarbons smaller than $C_{20}$. Therefore for bitumen and anthracene oil it would be expected to fail in the theoretical form as these oils have considerable portions of hydrocarbons larger than $C_{20}$. However, it indicated an exponential decrease in viscosity with temperature, which agrees with the observed behaviour of many liquids. From the above equation, an empirical correlation can be obtained for viscosity data of many fluids. This is:

$$\mu = A \exp (\Delta H/RT) \tag{1.16}$$

Where:

$\Delta H$ = Activation energy of viscosity (determined experimentally)

$A$ = System constant

$R$ = Universal gas constant

$T$ = Absolute temperature

The above equation is primarily useful for interpolation and extrapolation of viscosity data.

## 1.4 Survey of Previous Experimental Work

In order to determine if this work was necessary and to determine in what direction this investigation should proceed a review of previous experimental work investigating the rheology of coal-oil slurries was performed.

Prior to 1978 experimental work in attempting to determine the fundamental properties of coal in oil slurries was virtually non-existant. Gradishar et. al. (1943), [36] found good correlation between laboratory tests and pipeline test data for viscosity of coal-oil slurries. The slurry concentrations were below 40 wt% (-100 mesh, -150 $\mu$m) and flowing at Reynold's numbers less than 250. The tests were done at room temperature. The effect of varying concentration on viscosity was modelled using the Einstein equation, equation (1.14).

C. Moreland (1963), [36] performed tests using a Brookfield viscometer at various shear rates, various particle size distributions, and at 25°C for coal in mineral oil slurries. For concentrations less than 30 vol % Moreland found that the results were, again, fairly well represented by Einstein's equation, equation (1.14), with K lying between 2.65 and 3.15. Moreland reported pseudoplastic behaviour for concentrations above 10 vol% with the degree of pseudoplastic behaviour increasing with increasing concentration. Moreland also found a definite

dependence of slurry viscosity on slurry particle size distribution.

Since 1978 the amount of work done in coal-oil slurry property measurement increased considerably. This was mainly due to the United States' policy to reduce its dependence on imported oil by making use of other domestic sources of energy, one of these being its large reserves of coal. Therefore, with increasing research and development in coal liquefaction and the firing of boilers with coal and oil mixtures came increased interest in the fundamental properties of coal-oil slurries, one of these being viscosity. Most of this research was done in the United States although work was also performed in Australia, Canada, Great Britian and Japan.

Droege and Chauhan (1978), [13], performed experimental work on the viscous properties of mixtures of pulverized coal with solvent refined coal (SRC). These measurements were performed on Amax and Illinois #6 coal in 30 wt% mixture with their respective SRC's. Two viscometers were used, a falling cylinder type, and a coaxial cylinder type (Haake Rotovisco). Effects of temperature (up to 380°C) and time on viscosity were reported. The mixtures' shear rate behaviour was modelled using a Bingham plastic relationship.

Exxon Research (1978), [16], produced viscosity data on -30 mesh, -500 μm Illinois #6 and Wyodak coal slurried with light and heavy creosote oil. All experiments were

performed at solvent vapour pressure in a coaxial cylinder viscometer. For the Illinois coal a 41 wt% slurry was used. The slurries were reported to be Newtonian. The effect of temperature on viscosity was modelled by the equation:

$$\log \mu = \frac{A}{1.8T-459} + B \tag{1.17}$$

Where:

$\mu$ = slurry viscosity, cp

T = temperature, °K

A,B = system constants

This equation was reported to be applicable up to 200°C. Above 200°C coal swelling affected the viscosity. Viscosities of 22 wt% Illinois coal-oil slurry were reported up to a temperature of 332°C. The slurry was observed to be Newtonian with viscosity decreasing with temperature to 320°C and then showing a sharp rise in viscosity to 332°C due to coal swelling.

Castillo and Williams (1979), [9], performed experiments on slurries of Illinois #6 coal in Araclor 1254 and glycerine. Experiments were performed on various particle size distributions (-230 mesh [62 μm], -230 + 270 mesh [62 to 53 μm], -270 + 400 mesh [53 to 23 μm] and -400 mesh) and coal concentrations of 0, 20, 40, 50, 60 volume %. All of the measurements were made on a cone and plate viscometer (Weissenberg Rheogoniometer R-17) at 20°C. The

slurries are reported Newtonian up to 30 vol% coal concentration. Above 30 vol% coal the slurries were non-Newtonian and all exhibited shear thinning behaviour. The data did not fit any available model for viscosity dependence of dispersions of spherical particles. This shortcoming was explained by concentration effects, aggregation, effects of the fluid medium, and particle size effects.

Munro et. al. (1979), [37], reported experimental work on Northeastern Wyoming subbituminous coal in number 4 fuel oil. Experiments were performed on various particle size distributions (-150 + 170 mesh [104 to 90 μm], -170 +200 mesh [90 to 75 μm], -200 mesh) and coal concentrations of 0, 10, 20, 30, 40, 55 wt %. Measurements were performed in a modified Stromer concentric cylinder viscometer at temperatures of 25, 40, and 60°C. Below 30 wt% coal the slurries were reported to be Newtonian. Above 30 wt% the slurries were observed to be Bingham plastics. No attempt was made to model the temperature or particle size distribution effects. No dependence of slurry viscosity on particle size distribution was observed.

Kreusing, H. and Franke, F.H. (1979), [26], performed tests on coal-fuel oil slurries of 30 to 60 wt% coke, coal and lignite concentrations. The tests were carried out in a rotational viscometer (Haake) over a temperature range of 40 to 90°C. Eight different coal types were tested.

This was done to determine oil savings for coal-oil mixtures versus fuel oil alone. Therefore, no conclusive result of the effect of coal type on slurry properties were reported. However, the general results showed that 40 wt% coke-oil mixtures had the highest viscosity, mineral coal-oil slurry the lowest viscosity and lignite-oil slurry ranged in between the two. This effect was thought to be a function of the porosity of the coals although it was not thouroughly investigated. The effect of temperature on viscosity was reported as an expotential decrease in viscosity with increasing temperature. This effect was not modelled, however. The shear rate - shear stress relationship was not modelled but the mixtures were described as pseudoplastic. The effect of particle size distribution was also analysed. The authors stated that in order to achieve a minimum viscosity at a constant solid matter concentration the particle size distribution should correspond to the maximum packing density of the particles.

S. N. Bhattacharya and L. Barro (1980), [6], performed experimental work on Victorian Brown coal in a coal derived oil. The oil alone had a viscosity of 6.4 cp at 20°C. A close cut of coal particles was used (.085 mm to 0.06 mm, 0.072 mm average) to eliminate particle size as a variable. The viscometer used was a once through capillary tube type. These experiments were performed at atmospheric pressure and over a temperature range of

20-92°C. The coal concentrations considered were 20, 35, and 40 wt%. The 20 and 35 wt% supplies were reported as non-Newtonian with a yield stress below 30°C and Newtonian above 40°C. For a coal concentration of 40 wt% the rheological behaviour was non-Newtonian (shear thinning) with a yield stress over the entire temperature range. A decrease in apparent viscosity with increasing temperature was noted and the rate of change of viscosity decreased with increasing temperature. The rheological properties of the slurries were also observed to change with storage time (viscosity increased during storage).

Y. Yamagata et. al. (1980), [52], reported experimental work carried out with Australian "M" and China "D" coal in heavy fuel oil. Coal concentrations of 20 to 50 wt% were used. The temperature was varied from 20 to 80°C. The results of their work can be summarized with the following equations:

$$\mu_o = a \quad D^b \quad T^c \quad - \text{(for fuel oil only)} \qquad (1.18)$$

Where:

$\mu_o$ = apparent viscosity of fuel oil

D = shear rate

T = temperature

$a\ b\ c$ = constants

and

$\mu_a = \mu_o \,.\exp\, (K_2\, Cw/(1-K_1.Cw)$

Where:

$\mu_a$ = apparent slurry viscosity

Cw = concentration by weight of coal

$K_1, K_2$ = constants which depend on size distribution, particle form and intraction of coal and fuel oil.

The evidence and reasoning for arriving at these models was not clearly stated. Preliminary work on determining the effect of particle size distribution was also done. Capillary and concentric cylinder viscometer data were found to not correlate well.

G.R. Stefurak and B. Ozum (1981), [47, 39], conducted experimental work with subbituminous "Highvale" coal mixed with bitumen and anthracene oil. The coal was crushed to -100 mesh (-150 µm). The coal concentrations examined were 0, 10, 30, and 50 wt%. The shear rate range was 0 to 10 $s^{-1}$, and the temperature range was 20 to 70°C. The bitumen coal slurries were found to be basically Newtonian. The anthracene oil slurries were reported as pseudoplastic at the higher temperatures and coal

concentrations. The anthracene slurries were modelled using a two parameter power law model with no yield stress. For a constant concentration both K and n were found to decrease with increasing temperature. The temperature dependence of both anthracene and bitumen slurries were modelled using a rate theory equation develped by Eyring, equation (1.16). The data correlated well to this model. Coal concentration effect was discussed but no applicable model was presented.

P.C. Anderson et. al. (1981), [2], reported experimental results for slurries of 40 wt% coal (NCB rank 702) in heavy fuel oil. This work was performed using a coaxial cylinder rotational viscometer (Haake Rotovisco). The shear rate range was 1 to 650 $s^{-1}$ and the temperature range reported was 30 to 90°C. The slurries were non-Newtonian and slightly thixotropic. The shear behaviour of these slurries was modelled using a two parameter power law model with no yeild stress. The slurries were shear thinning with the consistency index typically between 0.8 and 1.0. The temperature effect on viscosity was reported but not modelled. The effect of coal concentration and slurry viscosity was modelled using

$$\eta_{rel} = \left[1 - \frac{1.7\ Cv}{0.64}\right]^{-1.6} \tag{1.20}$$

Where:

$\eta_{rel}$ = relative viscosity (viscosity of slurry/viscosity of oil)

$C_v$ = volume fraction of coal

Good correlation with the above equation was observed.

J.W. Droege et. al. (1981), [14], performed work to determine the viscosity of coal-oil slurries at conditions typical in a slurry preheater of a coal liquefaction process. The slurry was prepared from -200 mesh, -74 μm, #9 Kentucky coal and Wilsonville SRC recycle solvent in solvent to coal ratios (by weight) of 1.6, 2.0, 2.2, 3.0. The tests were performed over a temperature range of 300 to 650°K under a 14 MPa $H_2$ atmosphere. For this study Droege developed a coaxial cylinder viscometer with a reciprocating rather than rotating bob. The shear rate range of this instrument was -200 to +200 $sec^{-1}$. This peculiar viscometer design was developed to try and eliminate settling and to keep the slurry well mixed during the measurements. The viscous behaviour of the slurries was correlated with a Bingham plastic model. Considerable problems were encountered in reproducibility of data due to coal swelling, coking, and solids separation which made these results rather inconclusive. A possible logarithmic decrease in slurry viscosity with increasing temperature was reported.

M.R. Florez (1981), [17], reported the rheological behaviour of process streams in the Exxon Donor solvent

coal liquefaction process. The slurries were prepared from -30 mesh, -500 μm, Illinois and Wyodak coals in their respective hydrotreated recycle solvents. Slurry concentrations of 15, 30, 45 wt% were investigated over a temperature range of 25 to 440°C. These experiments were conducted at solvent vapour pressure in a coaxial cylinder rotational viscometer over a shear rate range of 20 to 2600 $sec^{-1}$. The 15 wt% slurries were Newtonian up to a shear rate of 2000 $sec^{-1}$, with some shear thickening behaviour observed at higher shear rates. The 30 and 45 wt% slurries were reported as non-Newtonian, shear thickening. The shear behaviour of these slurries was found to correlate well with a two parameter power law model. A plot of log reduced apparent viscosity ($^{\mu}a$ = $[\mu slurry/\mu solvent]_T$) versus inverse absolute temperature produced parallel linear correlations for all slurry concentrations.

Another project aimed at producing viscosity data at liquefaction process conditions was conducted at Oakridge National Research Laboratories by Lee, Oswald, Hightower, Youngblood, et.al., [27, 29-33]. These investigators have been developing a pipeline (capillary tube) viscometer system since 1978. Initial tests with -170 mesh, -85 μm Illinois #6 coal in Wilsonville recycle solvent (35 wt% coal) showed that slurry behaved as a power law fluid (shear thinning). The temperature range investigated was 400 to 700 K at (14 MPa) and the shear rate range was 100

to 600 $sec^{-1}$. A viscosity peak was observed at the gelation temperature of 572 K to 644 K. Below 400 K the slurry was described as Newtonian. In 1980/81, in preparation for the SRC-1 demonstration plant run work was carried out with Kentucky #9 coal, -170 mesh, -85 μm, and Wilsonville recycle solvent (35 wt% coal slurry). Data for these runs correlated equally well with a power law model and a Bingham plastic model.

General references [21,28,52] suggested that coal-oil slurries should behave as pseudoplastic fluids with no yield stress for coal concentrations above approximately 30 vol %. For lower concentrations the suspension should display the rheological behaviour typical of the suspending fluid. However as can be seen from the review presented above these generalities are not universally supplied by the experimental work.

Viscosity-temperature dependence generalizations for coal slurries were not available in the literature. However, from the experimental work where temperature effects were investigated and correlated an exponential or power type dependence of viscosity on temperature was suggested.

From previous work, then, it can be seen that general quantitative description of the effects of shear rate, temperature and coal concentration were not available. The large variation in previous experimental results was most likely due to the fact that the number of factors

that can affect slurry viscosity is very large (ie. solvent properties, coal type, coal particle size distribution, coal particle shape, chemical interactions, etc). With this in mind, it seems necessary to determine the viscosity data and behaviour for each particular slurry as it is required.

## 1.5 Experimental Apparatus and Procedure

This work investigated the flow behaviour of coal-anthracene oil and coal-bitumen slurries. The parameters which were varied, so that their effects on slurry viscosity could be determined, were the shear rate the temperature, and the coal concentration. The instrument used to measure the slurry viscosity was a Haake Rotovisco concentric cylinder viscometer. This unit was comprised of various components; an M-150 sensor head, a TP-24 electric heater-temperature controller, an MV-400-II cup and bob combination, and an RV-100 programmable controller-plotter. Details of the dimensions and capabilities of this equipment are shown in Table 1.1.

Table 1.1 Haake Viscometer - Physical Data

| | |
|---|---|
| Measuring Drive Unit: | Maximum Torque = 1.47 N-cm |
| | Maximum Speed = 500 rpm |
| Measuring System: | Rotor Radius = 18.4 mm |
| | Rotor Length = 60.0 mm |
| | Stator (cup) Radius = 21.0 mm |
| | Sample Volume = 55 $cm^3$ |
| Heater: | Temperature Range: Ambient to 400°C |
| | Control Variation: $\pm$ 0.1°C |

The viscometer was designed so that the shear rate could be varied from zero to a user specified value and back to zero again in a specified time period. This feature facilitated easy recognition of rheopectic or thixotropic behavior in the sample being tested. This feature also made possible the generation of a flow curve (shear stress versus shear rate) on the plotter in one experiment rather than many, as is usually the case with other instruments. The time period selected to cycle from zero shear rate to the full scale shear rate and back to zero shear rate was eight minutes for all experiments. This time was used because it would make unsteady flow effects as well as viscous heating effects negligible. The linear scales of the plotter output were converted directly to shear stress (Y-axis), in Pa, and shear rate (X-axis), in $s^{-1}$ using numerical multiplication factors given for the particular cup and bob combination used. In this study the shear stress scale factor was 1.13, and the shear rate scale factor was 4.50. Only one cup and bob combination was used throughout the work. Figure 1.3 shows a typical viscometer plotter output.

The slurries used in this study were prepared containing 0, 10, 30, and 50 weight percent coal using anthracene oil and bitumen as solvents. The coal used was an Alberta subbituminous, "Highvale" coal acquired from a strip mine near Wabamun Alberta. The coal was pulverized to less than 150 micron maximum particle size and oven

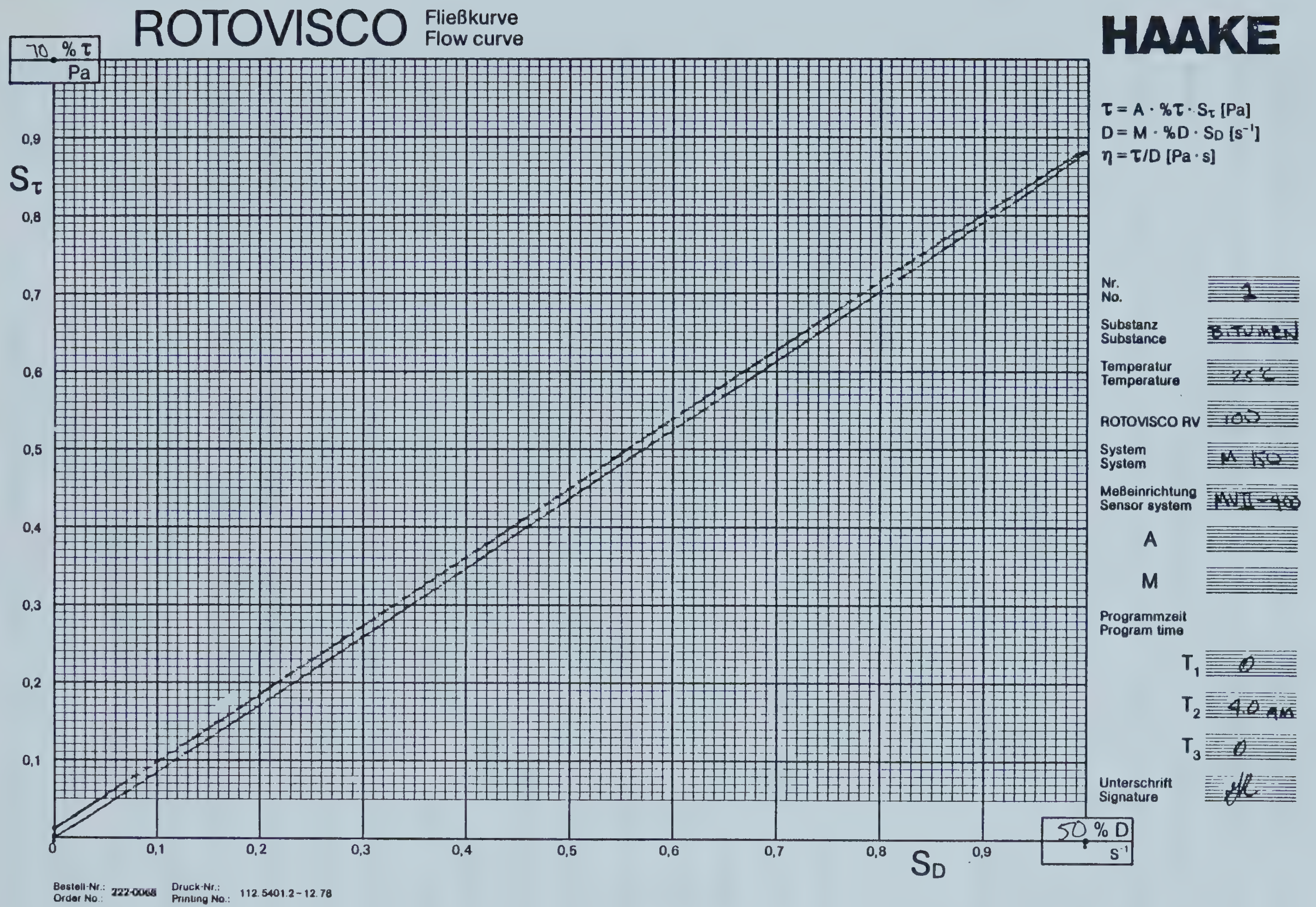



Figure 1.3 Typical Haake Viscometer Output

dried at 70°C under vacuum prior to the slurry preparation. The bitumen was Suncor coker feed bitumen obtained from the Suncor Oilsands plant near Fort McMurray, Alberta. The anthrancene oil, a by-product of coking coal for the steel industry, was obtained from Stelco in Hamilton, Ontario. Laboratory analyses of the coal and the two solvents are provided in Table 1.2. The particle size distribution of the coal used is given in Appendix A. A summary of the experiment variables investigated is given in Table 1.3.

The procedure for this investigation was to introduce the slurry into the cup of the viscometer, mix it well, and then measure the temperature of the fluid using a thermocouple placed into the fluid. If the temperature was stable, the thermocouple was removed and a flow curve was then generated. After the measurement was complete the slurry temperature was checked to see if it had changed. If the temperature differed from the initial measured value by more than 0.2°C the run was repeated. This value of 0.2°C was chosen because the heater had a published temperature control capability of $\pm$0.1°C. After a successful run the temperature setting of the heater was then increased by 15°C and the preceding steps were repeated. When the final temperature of 150°C was reached the sample was cooled and measurements were taken at approximately 25°C temperature intervals until ambient conditions were again reached. When all the viscosity

Table 1.2 LABORATORY ANALYSIS OF COAL, ANTHRACENE OIL AND BITUMEN

Coal: Highvale Subbituminous, Pulverized to -150 μm, dried

| | % |
|---|---|
| Moisture | 8.86 |
| Ash | 10.72 |
| Volatile Matter | 31.83 |
| Fixed Carbon | 48.59 |

Anthracene Oil:

| | % |
|---|---|
| Asphaltenes | 3.36 |
| Resins | 14.2 |
| Oils | 82.2 |
| Elemental Analysis (92.1% C, 5.35% H, 0.55% N, 0.96% S, 1.13% O) | |

Bitumen:

| | % |
|---|---|
| Water | < 0.5 |
| Ash | 0.5 - 1.0 |
| Residual naphtha | < 3.0 |
| Asphaltenes | 13.1 - 15.5 |
| Elemental Analysis (82.6% C, 10.6% H, 0.8% N, 3.7% S, 1.6% O) | |

Table 1.3 EXPERIMENTAL VARIABLES

| | |
|---|---|
| Coal: | Alberta Subbituminous (Highvale) - 150 micron |
| Coal Concentration: | 0, 10, 30, 50% by weight |
| Solvents: | 1) Anthracene Oil<br>2) Bitumen |
| Temperature Range: | 25° to 150°C |
| Shear Rate Range: | Variable 0 to 1170 $s^{-1}$ Max. |

measurements for a particular slurry were complete the instrument was cleaned and the calibration was checked using viscosity standards of 10, 1.0 and 0.1 Pa-s absolute viscosity at 25°C. After the calibration check, the above procedure was repeated for the next slurry. Since there was no cooling capability on the heater, and, therefore, temperature control was determined by natural convection to the surrounding air, no attempt was made to exactly duplicate the temperatures at which the viscosity measurements were taken for each particular slurry. The repeatability of the experiments was checked by repeating a viscosity measurement of each particular slurry at a temperature where the viscosity had been measured previously.

## 2.0 RESULTS AND DISCUSSION

This section reports and discusses the effects of shear rate, temperature, and coal concentration on the apparent viscosities of the two coal-oil slurries investigated.

### 2.1 Coal-Anthracene Oil Slurries

#### 2.1.1. Shear Rate Behaviour

Anthracene oil and coal-anthracene oil slurries were subjected, depending on temperature and coal concentration to shear rates ranging from 0 to 1170 $s^{-1}$. Anthracene oil alone was slightly shear thinning (psuedoplastic) at low temperatures (25-40°C). As the temperature was increased, however, the behaviour changed gradually to a slight shear thickening (dilatant) nature at high temperatures (140-150°C). The transition in the observed flow behaviour from pseudoplastic to dilatant occurred at a temperature in the range of 45 to 60°C. This temperature range also corresponds to that at which a change was observed in physical composition and consistency of anthracene oil. Below approximately 60°C anthracene oil had a somewhat waxy crystalline structure. This would possibly provide an explanation for the slight shear thinning behaviour of the oil at low temperatures. As the crystalline structure was broken down by the shearing of the fluid between the cylinders of the viscometer the

relative resistance to flow of the oil would be expected to decrease somewhat. At the higher temperatures, where the crystalline structure had been destroyed, anthracene oil became a slightly dilatant fluid.

When coal was added to the anthracene oil the shear thickening behaviour at higher temperatures was suppressed. As the coal concentration was increased the slurries tended to become slightly psuedoplastic in nature. Below coal concentration of 50 wt% however, the deviation from Newtonian behaviour was not large enough to warrant the use of a non-Newtonian shear stress - shear rate model. Typically the least squares linear curve fit the shear stress versus shear rate data did not have a correlation coefficient less than 0.99. Figures 2.1, 2.2 and 2.3 show typical shear stress versus shear rate plots for 0, 10 and 30 wt% coal-anthracene oil slurries, respectively, at temperatures near 50°C. As can be seen the deviation from linearity (Newtonian behaviour) was negligible. Shear stress versus shear rate data is included in Appendix C.

The 50 wt% coal-anthracene oil slurry was significantly pseudoplastic in nature over the entire temperature range investigated. Figure 2.4 shows a typical shear stress versus shear rate plot for the 50 wt% coal-anthracene oil slurry near 50°C. It can be seen from this plot that the deviation from Newtonian behaviour is significant. For the 50 wt% coal-anthracene slurry

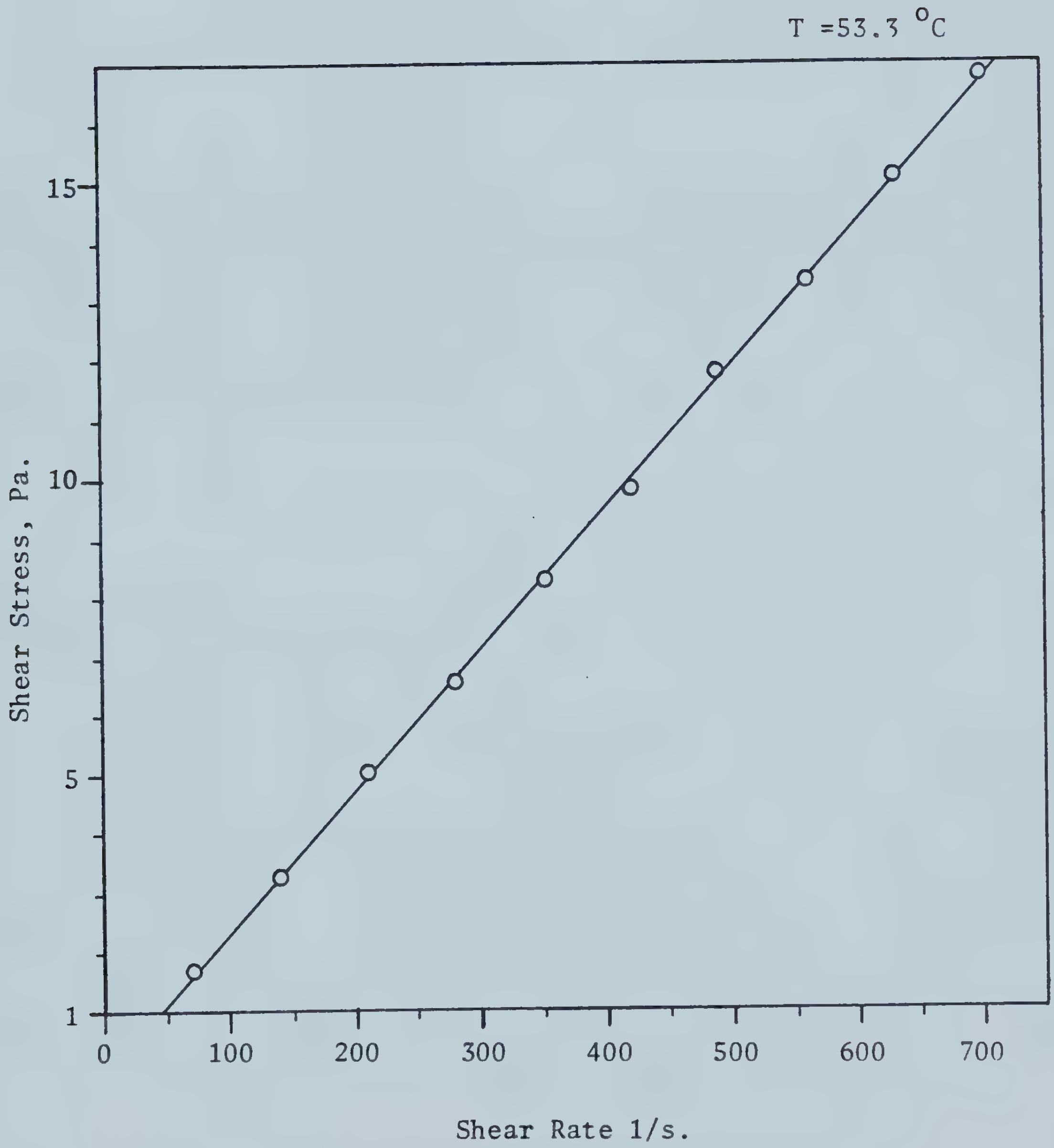



Figure 2.1 Shear Stress versus Shear Rate Plot
Anthracene Oil

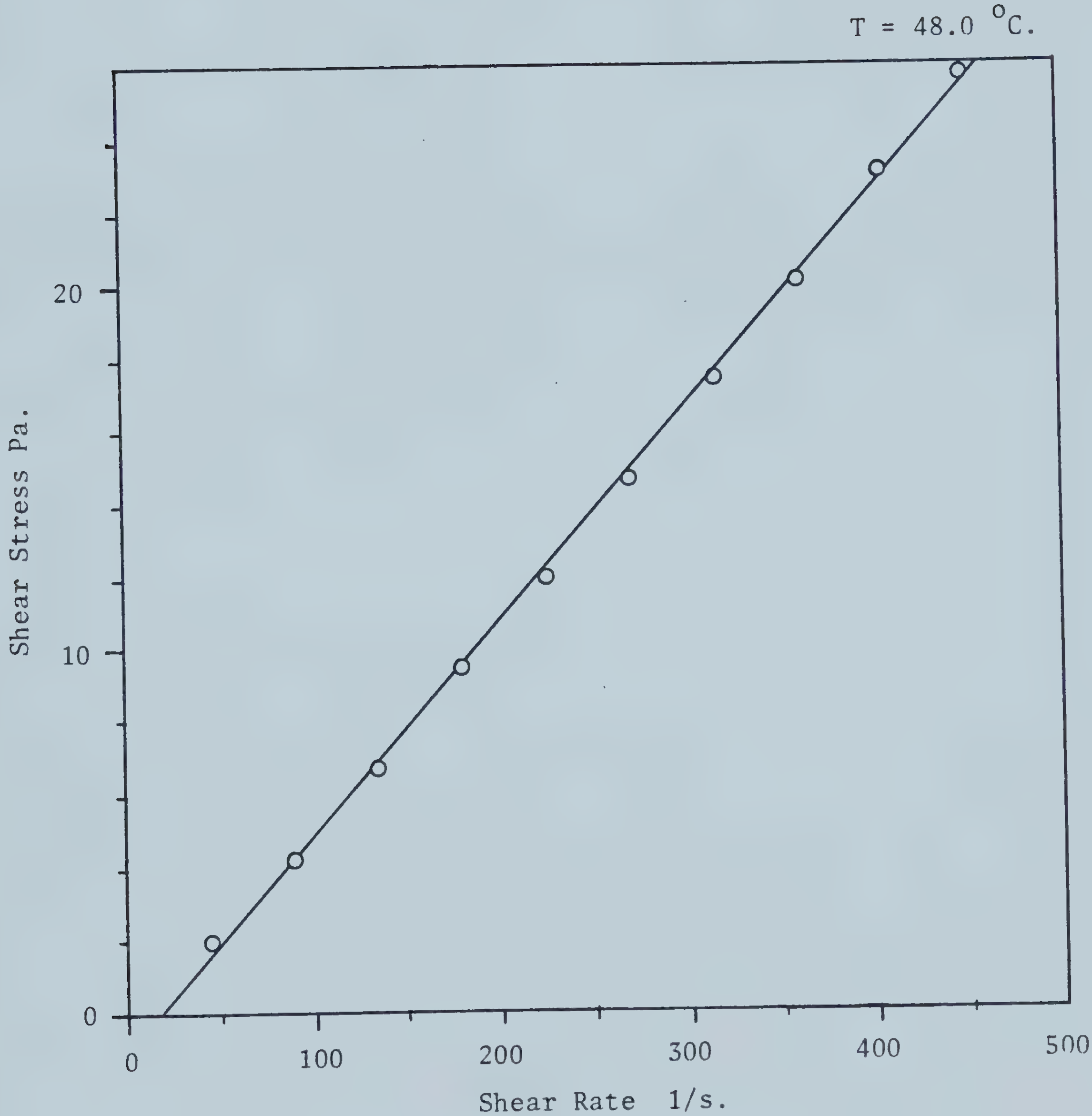



Figure 2.2 Shear Stress versus Shear Rate Plot
10 wt% Coal-Anthracene Oil Slurry

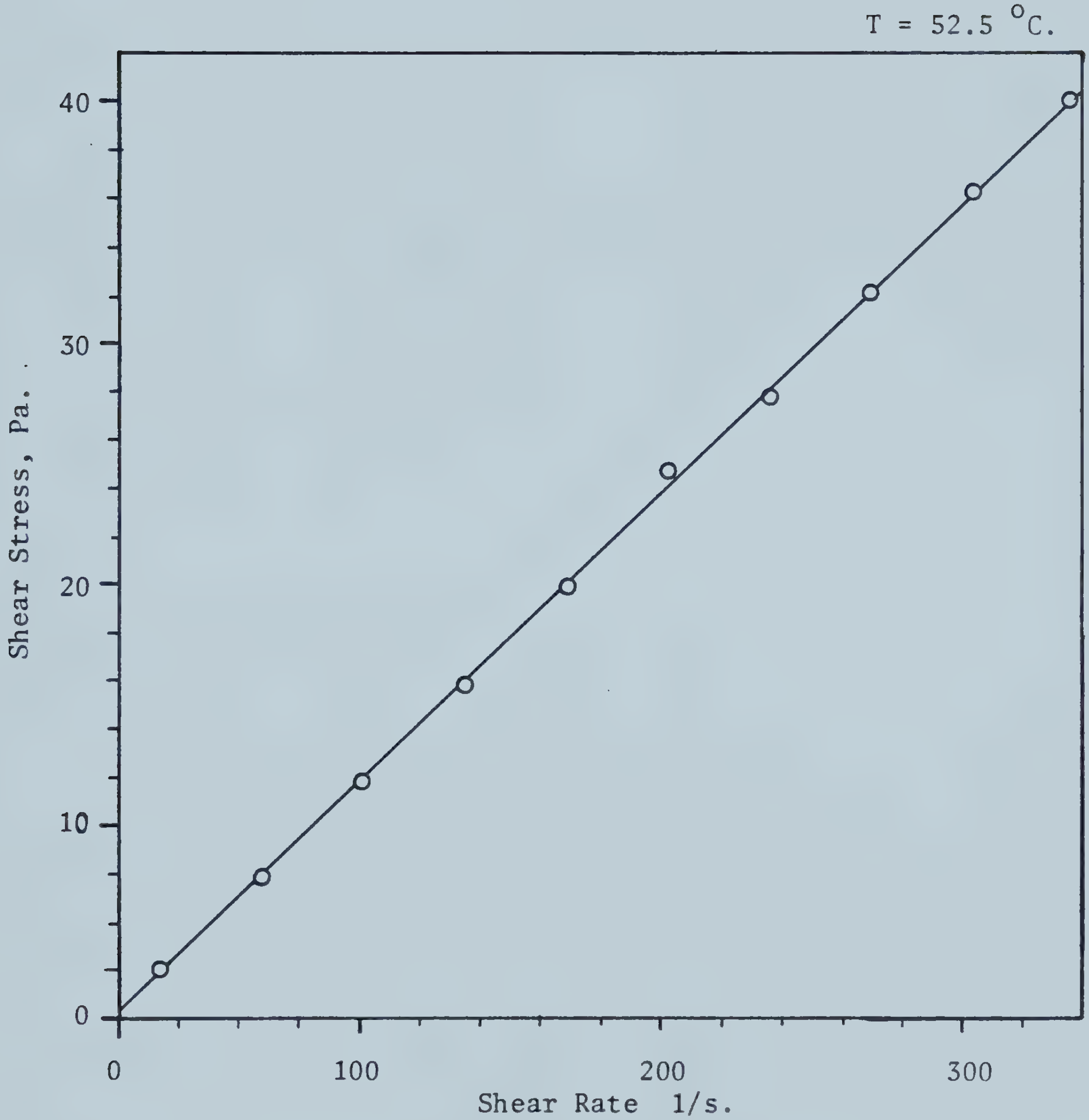



Figure 2.3 Shear Stress versus Shear Rate Plot
30% wt% Coal-Anthracene Oil Slurry

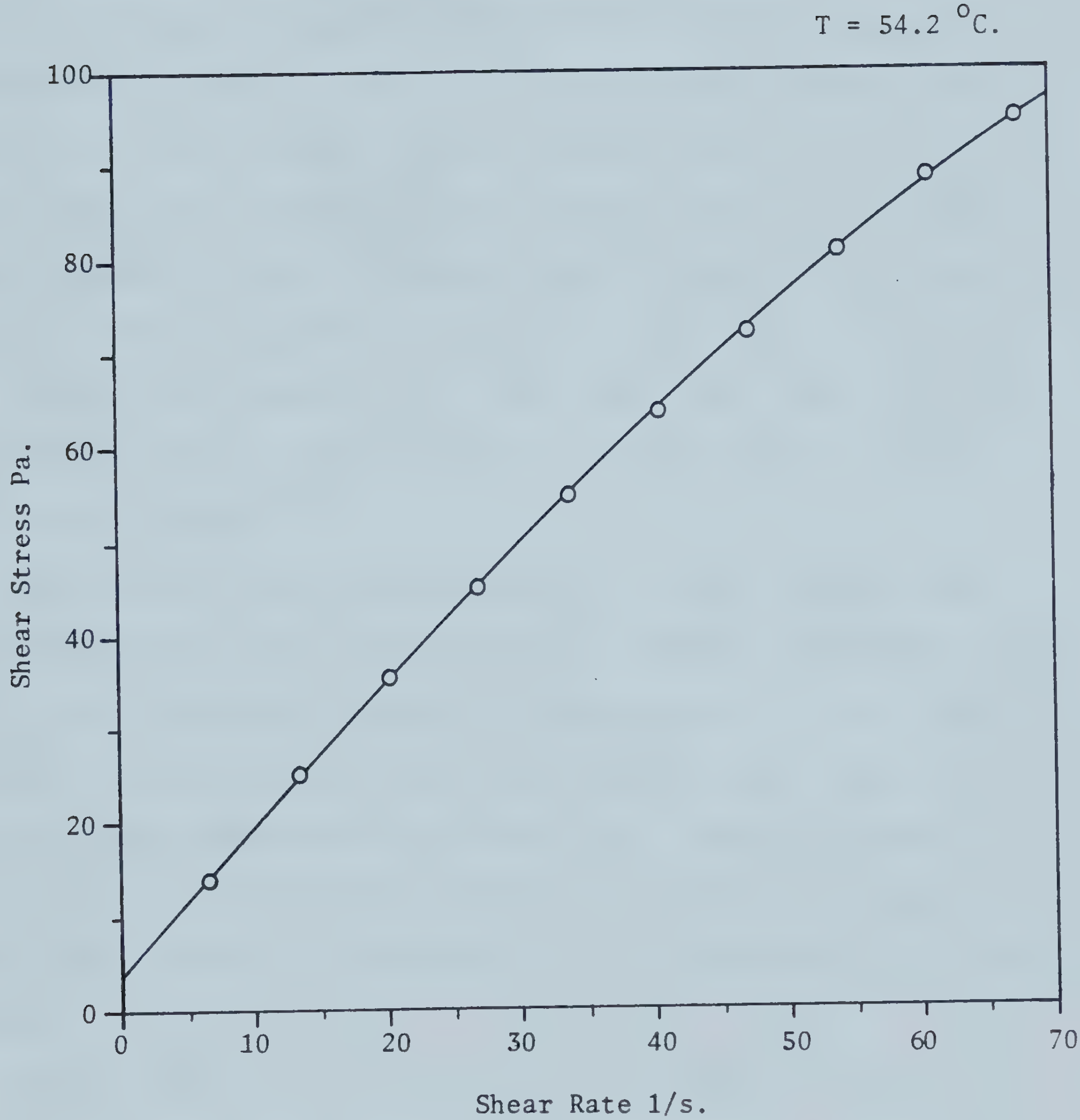



Figure 2.4 Shear Stress versus Shear Rate Plot
50 wt% Coal-Anthracene Oil Slurry

the two parameter power law model, equation (1.3), was used to correlate the data. Table 2.1 presents the results of this correlation for several temperatures. The flow consistency index, K, and the flow behaviour index, n, values in Table 2.1 were calculated from a linear least squares fit to the log (shear stress) versus log (shear rate) data. The slope of this data being n, the intercept being Log (K). The correlation coefficient, $r^2$, in Table 2.1 indicates the linearity of such a fit. As can be seen the power law model fit the data for the 50 wt% coal-anthracene oil slurry for the 50 wt% coal-anthracene oil slurry very well.

The pseudoplastic behaviour of the high concentration coal-anthracene oil slurry could at least, partially be due to the irregular shape of the coal particles. When shearing was applied to the slurry these particles would tend to align themselves with the flow. This alignment of the particles, as the shear rate increased, would tend to reduce the relative resistance to flow generated by the system.

Trends that should be noted in the data presented in Table 2.1 are that the flow consistency index, K, decreased considerably with increased temperature and the flow behaviour index, n, tends to increase slightly with increased temperature. This result was different than previous experimental work [47] which reported decreasing

Table 2.1 POWER LAW PARAMETERS - K AND n - 50 WT% COAL-ANTHRACENE OIL SLURRY

| Temperature (K) | K (Pa-s) | n | Correlation ($r^2$) |
|---|---|---|---|
| 317.7 | 10.6739 | 0.8326 | 0.9997 |
| 327.4 | 2.9023 | 0.8329 | 0.9998 |
| 357.5 | 0.4430 | 0.8757 | 0.9989 |
| 396.4 | 0.1427 | 0.8888 | 0.9974 |
| 418.0 | 0.0672 | 0.9180 | 0.9998 |

K and n values with increasing temperature [39].

### 2.1.2. Temperature Behaviour

Viscosity data for Anthracene oil and anthracene oil-coal slurries were collected over a temperature range of ∿25 to 150°C in both heating and cooling. The data was then correlated using equation (1.6), had this model been valid for the coal-anthracene oil slurries a semi-logarithmic plot of apparent viscosity versus inverse absolute temperature should be produced linear curves of slope $\Delta H/R$, as described in section 1. . As can be seen from Figures 2.5 and 2.6 which depict the coal-anthracene oil slurry apparent viscosity variation with temperature in heating and cooling respectively the curves were not particularily linear. The non-linearity of the heating data Figure 2.5, could, in part, be due to evaporation of part of the liquid sample during the heat up phase of the experiments. The cooling data, Figure 2.6, produced more linear curves than the heating data. A linear least squares fit was performed on the cooling data and the results of this fit is shown in Table 2.2. The data correlated fairly well with a linear fit ($r^2$min=0.8499). The notable feature of the results in Table 2.2 is that the activation energy of flow, $\Delta H$, remains nearly constant for all of the coal concentrations with the exception of the 50 wt% slurry. This would indicate that $\Delta H$ is

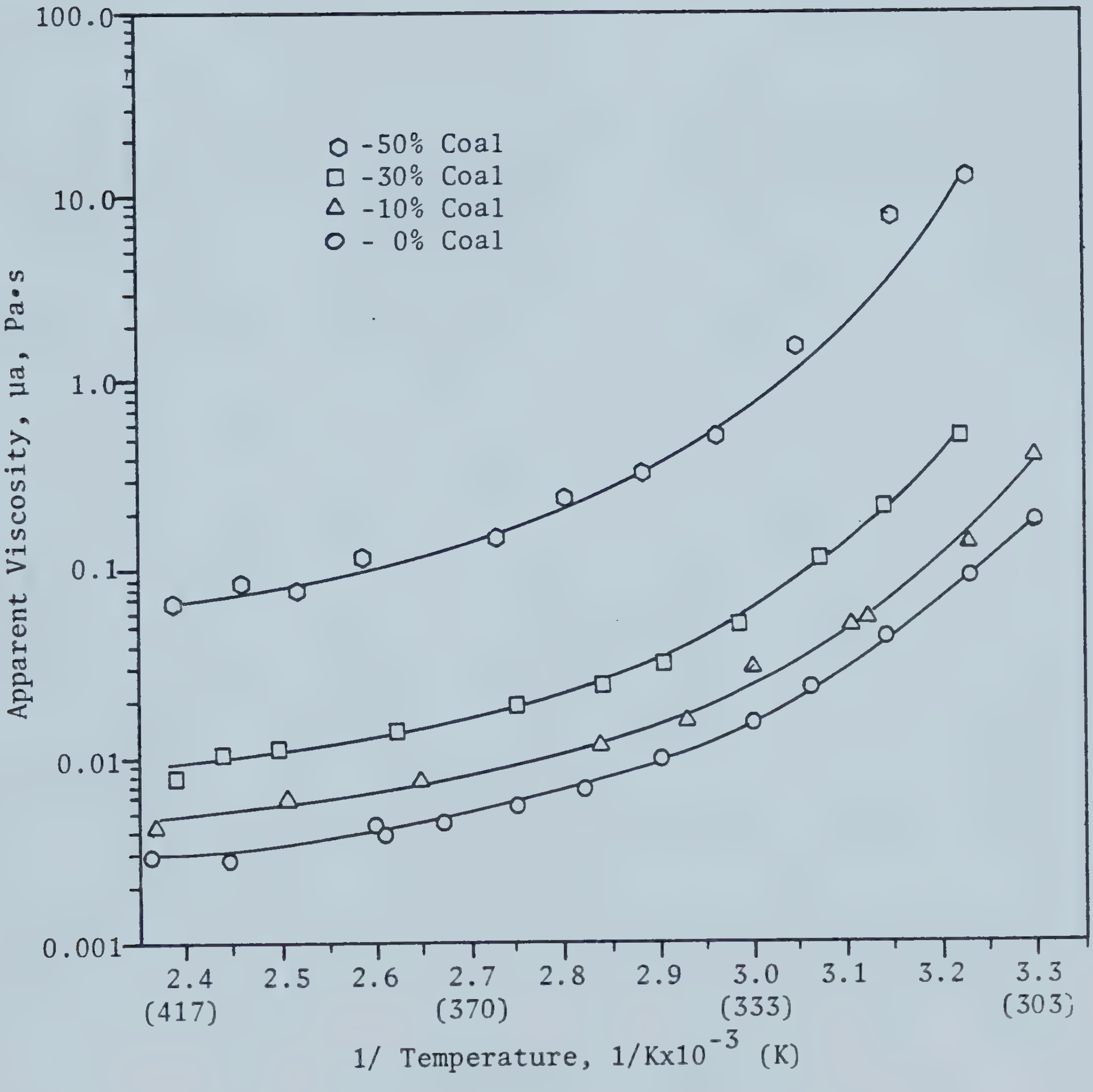



Figure 2.5 Coal-Anthracene Oil Slurry Apparent Viscosity versus Inverse Temperature Plot - Heating

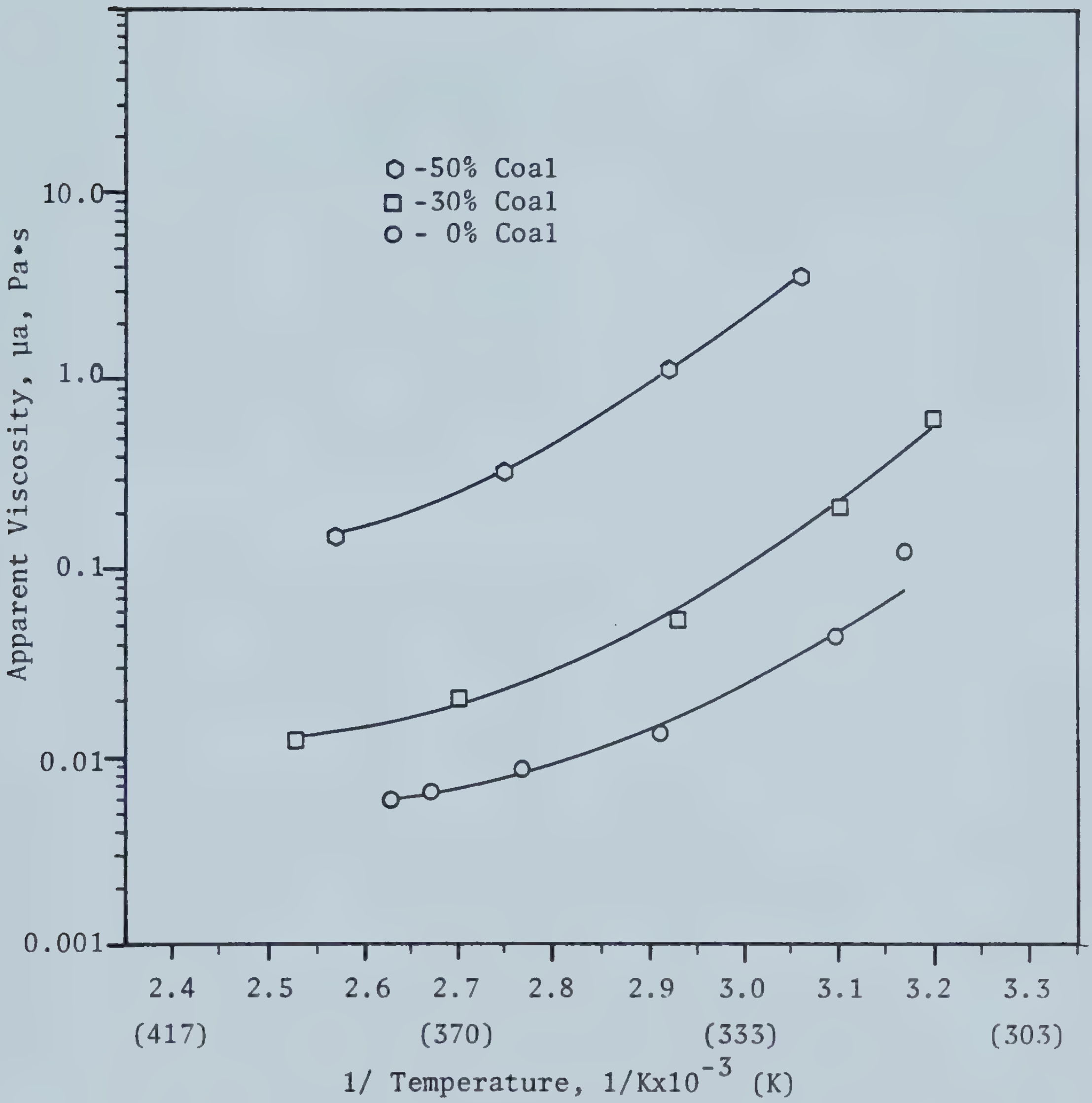



Figure 2.6 Coal-Anthracene Oil Slurry Apparent Viscosity versus Inverse Temperature Plot - Cooling

Table 2.2 COAL-ANTHRACENE OIL SLURRY ACTIVATION ENERGY OF FLOW

| Coal Conc. (wt%) | H (kJ/kg mole-K) | Correlation ($r^2$) |
|---|---|---|
| 0 | 8.789 | 0.9222 |
| 10 | 8.932 | 0.8499 |
| 30 | 8.272 | 0.9733 |
| 50 | 10.08 | 0.9715 |

relatively insensitive to solids concentration and is determined by the suspending fluid. This result was reported in previous experimental work [39].

The non-linearity of the curves in Figure 2.6 was possible due to the complex physical nature of the anthracene oil, as was previously noted. It should be noted, however, that the instantaneous slope of all the curves in Figure 2.5 and 2.6 are nearly equivalent. This would indicate that the activation energy of flow for the anthracene oil slurries may be temperature dependent but was still relatively insensitive to changes in coal concentration.

## 2.2 Coal-Bitumen Slurries

### 2.2.1 Shear Rate Behaviour

Bitumen and coal-bitumen slurries were subjected to the same test conditions as the anthracene oil slurries (Section 2.1.1). The results obtained for the bitumen slurries were generally comparable to those of the anthracene oil slurries. Bitumen, without coal added, behaved almost perfectly Newtonian. Unlike the anthracene oil, bitumen was a physically homogeneous liquid throughout the temperature range investigated. With the addition of coal to the bitumen a slightly pseudoplastic character was observed. This behaviour was also previously observed in the anthracene oil slurries; (Section 2.1.1). For the bitumen slurries, as with anthracene oil slurries, the deviation from Newtonian behaviour was not significant until a coal concentration of 50 wt% was reached. At 50 wt% coal concentration the bitumen slurries exhibited a definite pseudoplastic character. Figures 2.7, 2.8 and 2.9 illustrate the typically Newtonian behaviour of the 0, 10 and 30 wt% coal-bitumen slurries, respectively. Figure 2.10 depicts the definite pseudoplastic nature of the 50 wt% coal-bitumen slurry.

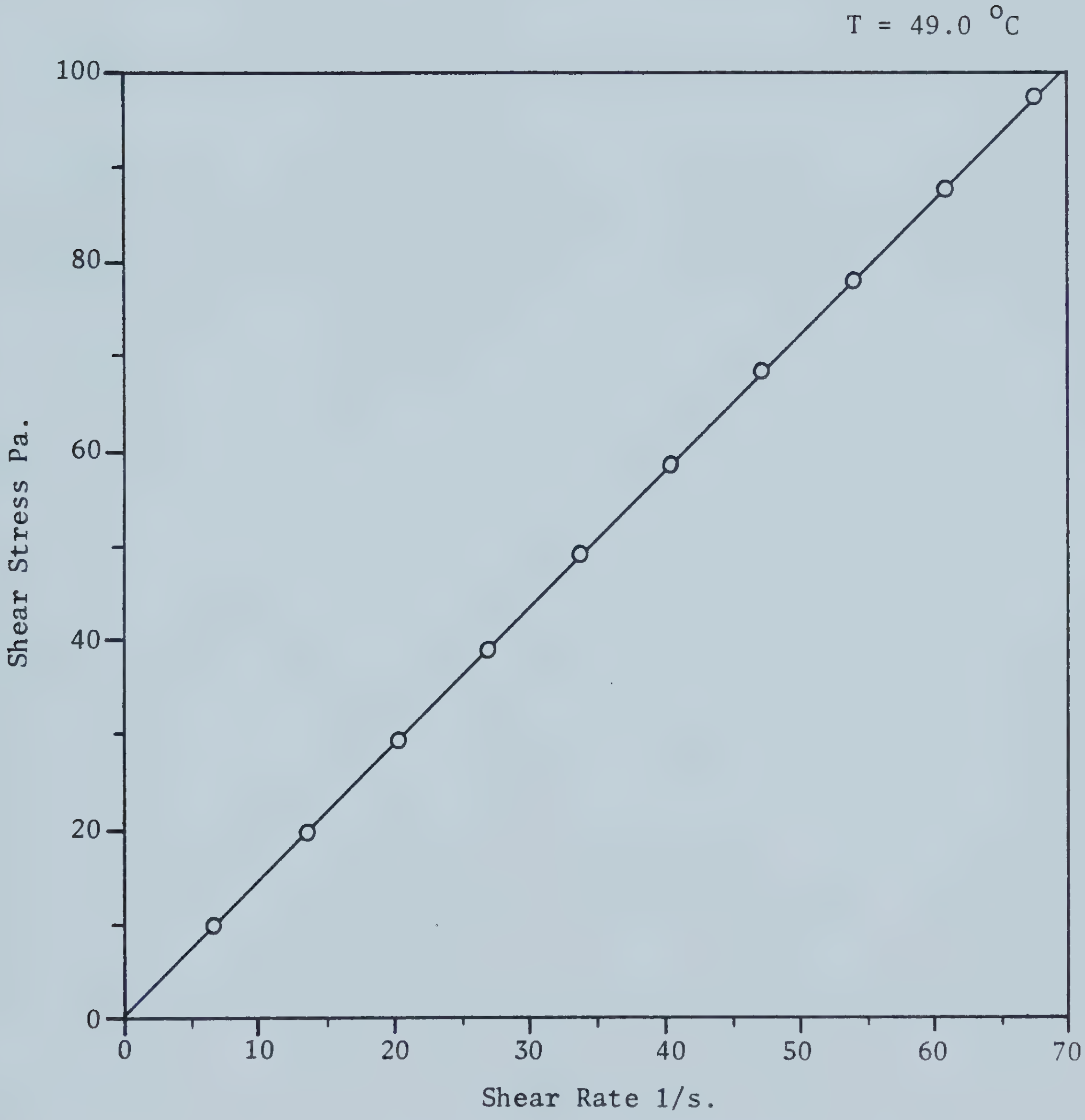



Figure 2.7 Shear Stress versus Shear Rate Plot
Bitumen

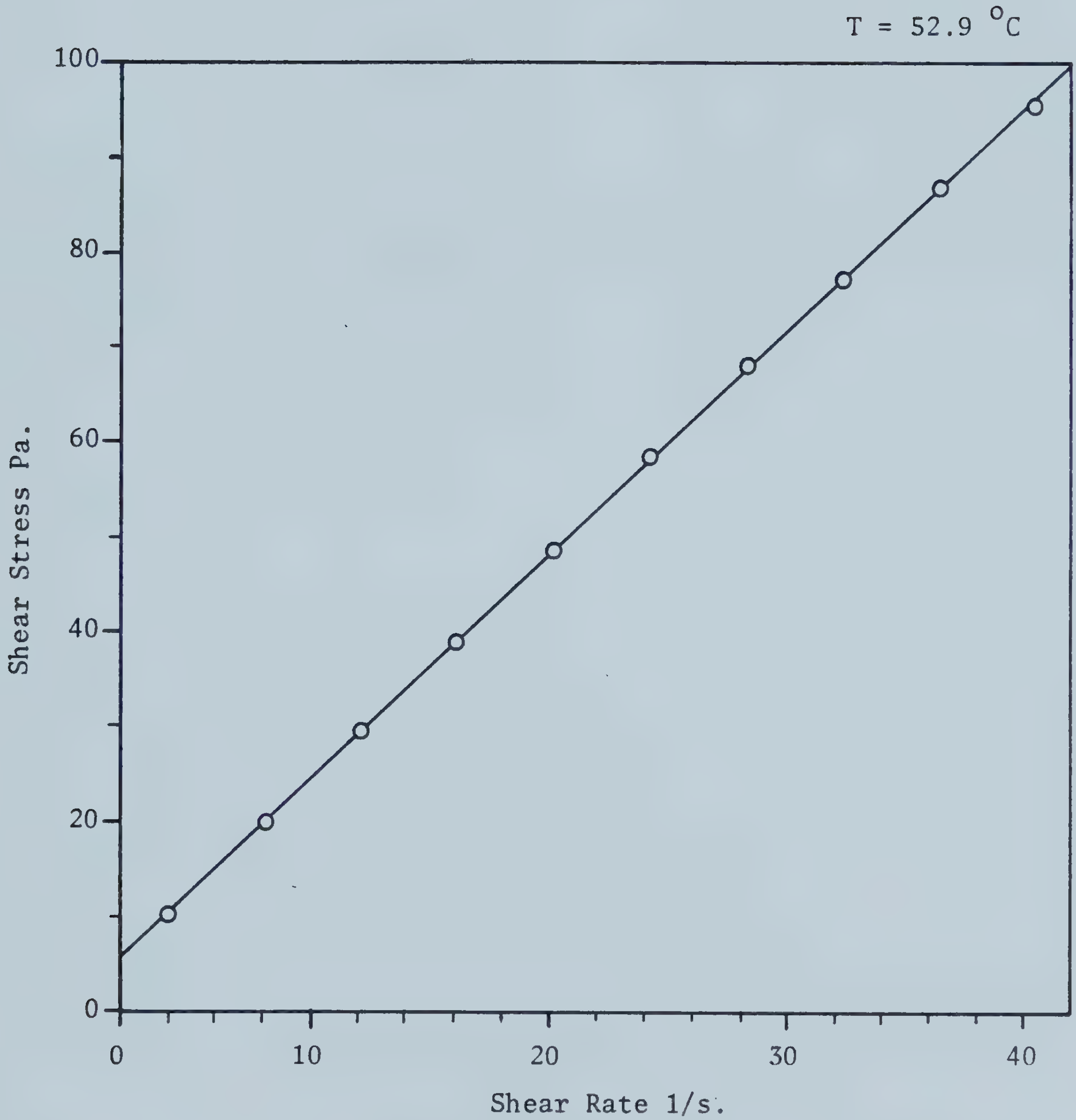



Figure 2.8 Shear Stress versus Shear Rate Plot
10 wt% Coal-Bitumen Slurry

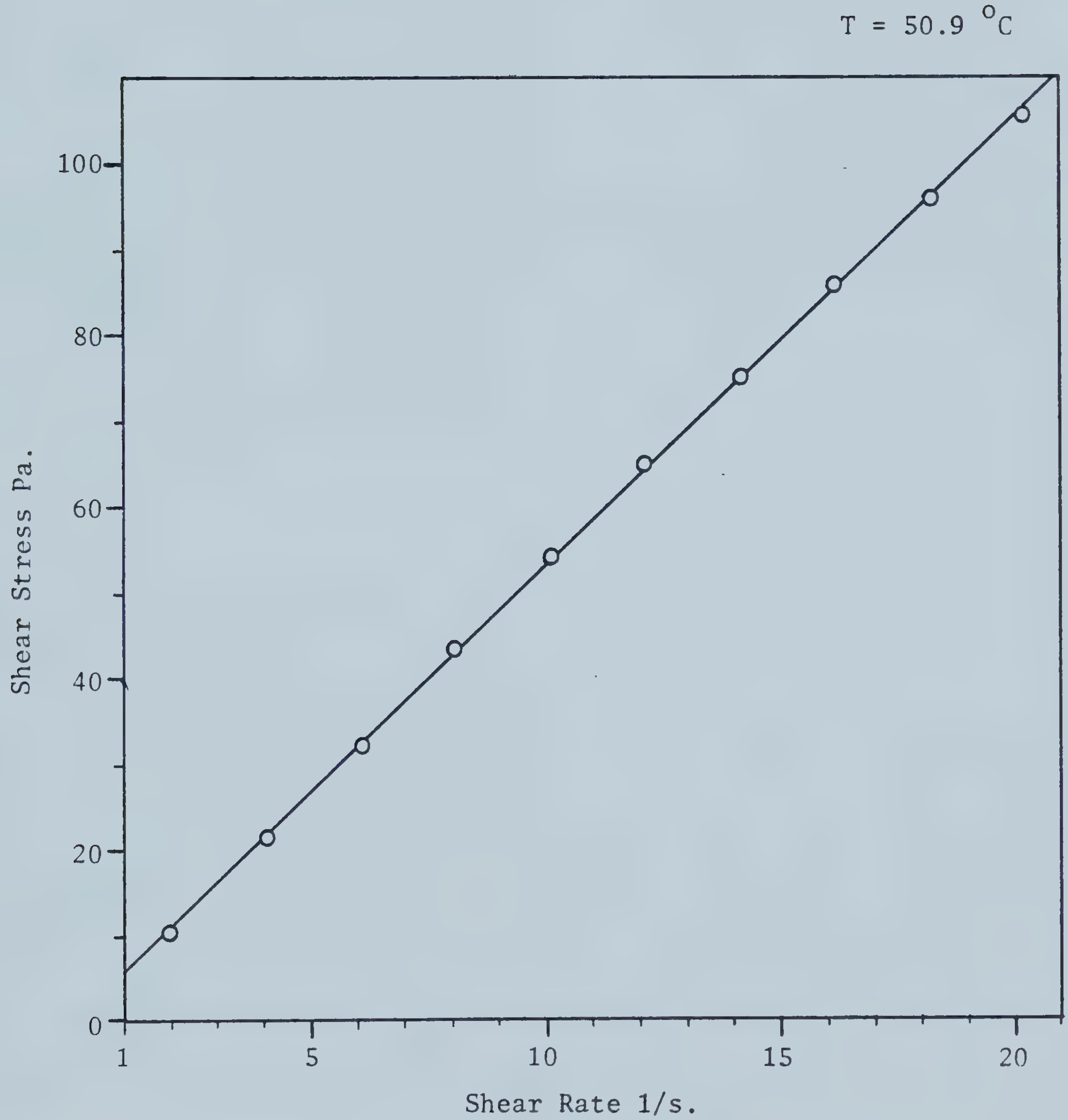



Figure 2.9 Shear Stress versus Shear Rate Plot
30 wt% Coal-Bitumen Slurry

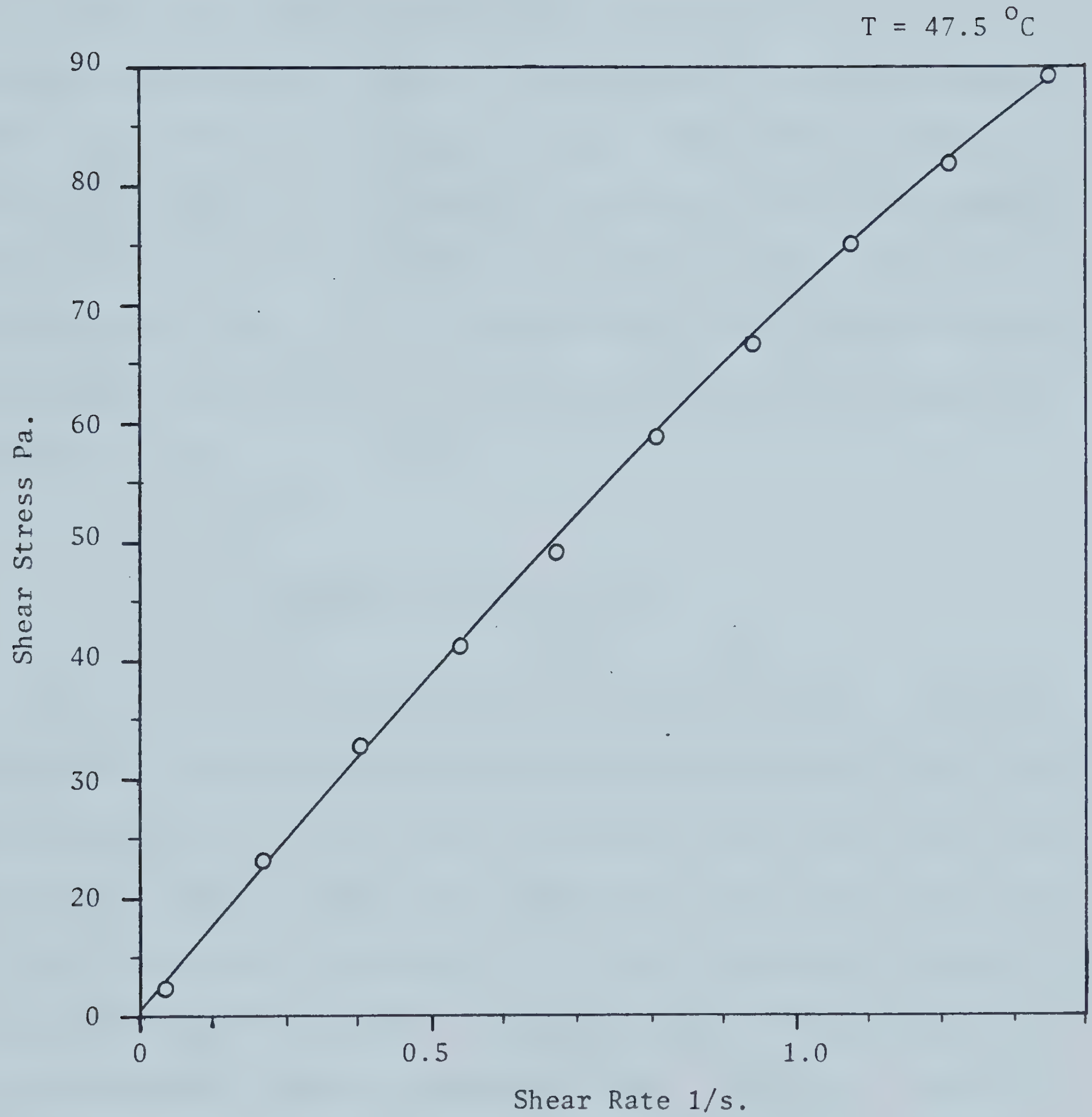



Figure 2.10 Shear Stress versus Shear Rate Plot
50 wt% Coal-Bitumen Slurry

The 50% coal-bitumen data was also correlated using a two parameter power law model, equation (1.3). The results of this correlation are given in Table 2.3.

As was the case for the coal-anthracene oil slurries the flow consistency index, K, exhibited a large decrease with increasing temperature while the flow behaviour index, n, showed a slight increase with increasing temperature. The power law model fit the data exceptionally well as is reflected by the values of the correlation coefficients, $r^2$, which were all very near to a value of 1.0.

### 2.2.2 Temperature Behaviour

The variation with temperature of the apparent viscosities of coal-bitumen slurries was also fit with the model equation (1.16). Figures 2.11 and 2.12 show the semi-logarithmic plots of apparent viscosity versus inverse absolute temperature for coal-bitumen slurries during heating and cooling, respectively. The result was a significantly better agreement with the model equation than was observed for the coal-anthracene oil slurries. The cooling data shows exceptionally good agreement. A least squares fit of the cooling data was performed and the results of this are given in table 2.4. In this case the linearity of the data was excellent, as compared with the coal-anthracene oil slurries (Table 2.2). The

Table 2.3 POWER LAW PARAMETERS - K AND n - 50 WT% COAL-BITUMEN SLURRY

| Temperature (K) | K (Pa-s) | n | Correlation ($r^2$) |
|---|---|---|---|
| 320.7 | 69.8062 | 0.8537 | 0.9997 |
| 327.2 | 32.3105 | 0.8244 | 0.9929 |
| 360.8 | 6.1178 | 0.8917 | 0.9997 |
| 401.2 | 1.4654 | 0.9188 | 0.9998 |
| 420.2 | 0.9641 | 0.9136 | 1.0000 |

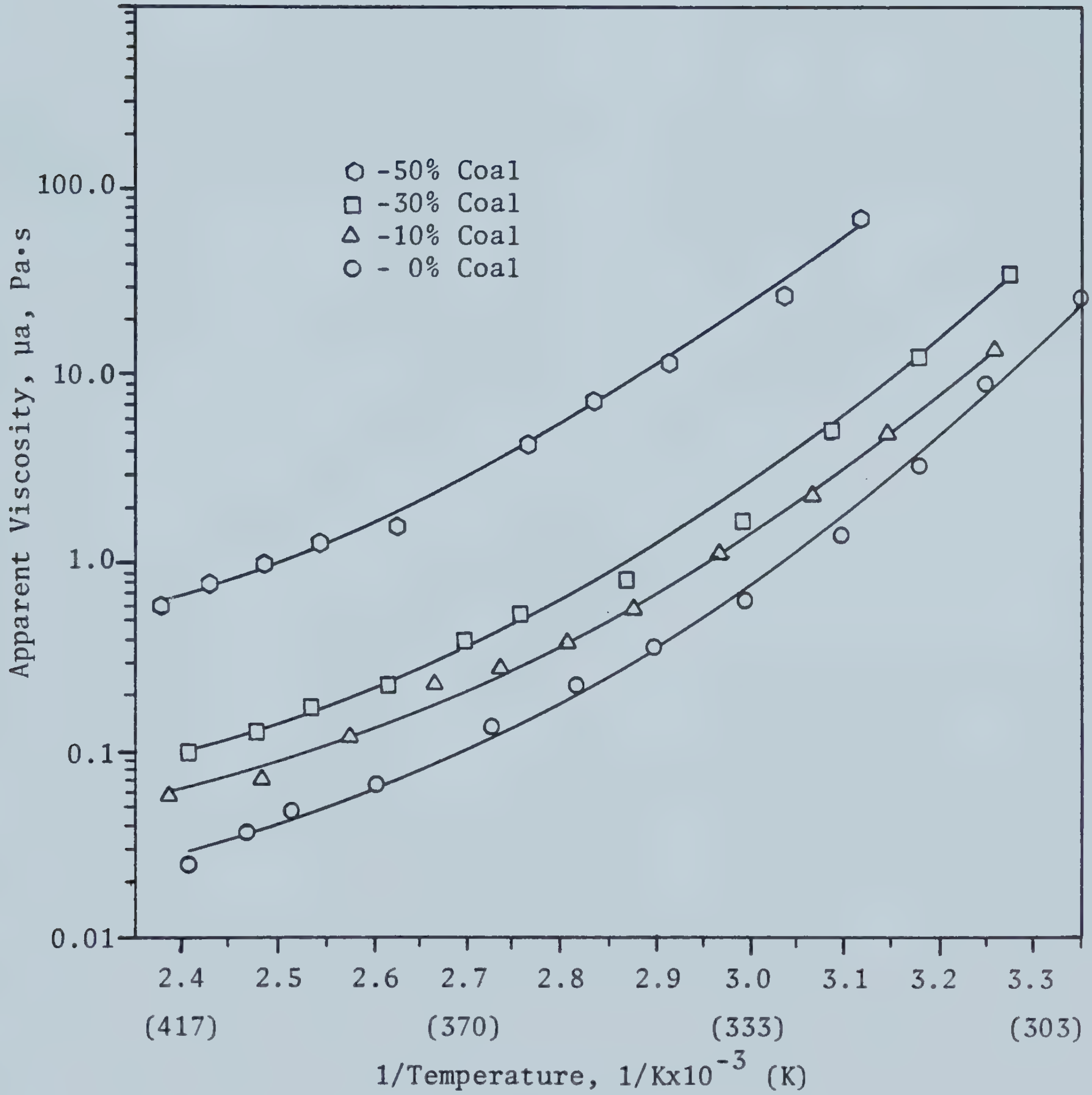



Figure 2.11 Coal-Bitumen Slurry - Apparent Viscosity versus Inverse Temperature Plot - Heating

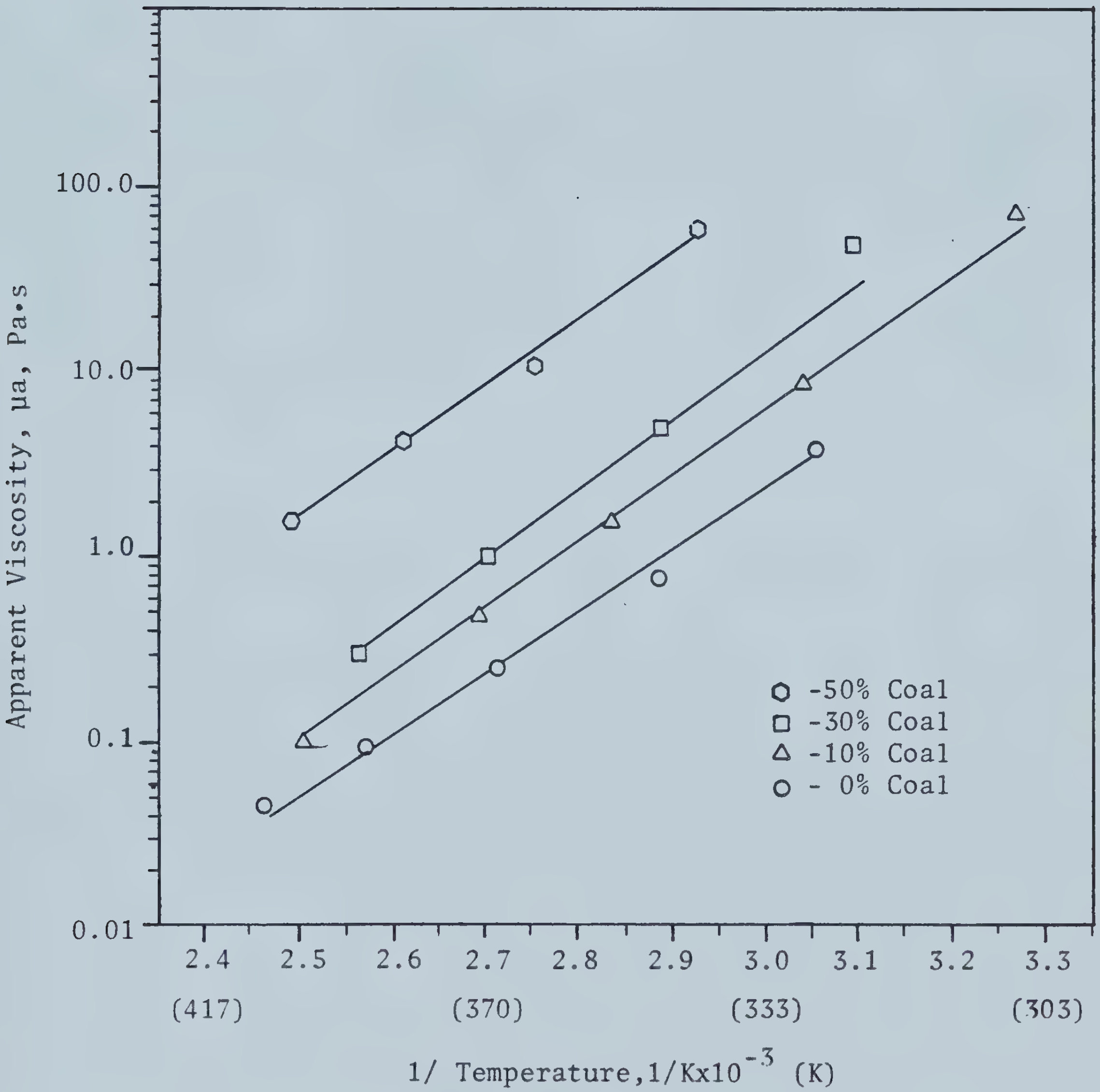



Figure 2.12 Coal-Bitumen Slurry Apparent Viscosity versus Inverse Temperature Plot - Cooling

Table 2.4 COAL-BITUMEN SLURRY ACTIVATION ENERGY OF FLOW

| Coal Conc. (wt%) | H (kJ/kg mole-K) | Correlation ($r^2$) |
|---|---|---|
| 0 | 11.79 | 0.9945 |
| 10 | 13.58 | 0.9992 |
| 30 | 15.01 | 0.9967 |
| 50 | 12.89 | 0.9843 |

activation energy of flow, $\Delta H$, however, was not as consistent in value as was the case with anthracene oil. A dependence of $\Delta H$ on coal concentration is not apparent, however. The scatter observed in the data may have been due to the limited number of experiments conducted during cooling. Therefore, it would be reasonable to conclude that the activation energy of flow for the coal-bitumen slurries was a constant value in the range of 12 to 15 kJ/kg-mole-°K and was independent of coal concentration, (i.e.) it was a property of the bitumen alone. This result was consistent with previous experimental work [39].

The non-linearity of the heating curves, Figure 2.11, was most likely due to the significant evaporation of bitumen which was observed during the course of the experiments. Thermo Gravimetric Analysis (TGA) were conducted on bitumen and coal-bitumen slurries in order to attempt to quantify the evaporation of the bitumen solvent during the measurements. These TGA curves are included in Appendix B. Generally the amount of bitumen evaporation was $\sim$10% by weight of the sample. As the temperature increased from $\sim$25 to 150°C the lighter hydrocarbons in the bitumen evaporated. Therefore the apparent viscosity of the material would be expected to increase. The increase in apparent viscosity would explain the concave curves shown in Figure 2.11.

## 2.3 Coal Concentration Effect

The effect of coal concentration on apparent slurry viscosity was investigated over a range of 0 to 50% by weight coal. The reduced slurry viscosity ($\mu_a$ slurry/$\mu_a$ solvent, calculated at a common temperature) and the volume concentration of coal were calculated and the results are plotted in Figures 2.13 and 2.14 for temperatures of approximately 50°C and 120°C respectively. The volume concentration of coal was calculated knowing the weight percent concentration and the density of the coal and the two solvents, ($\rho$ coal=1.6 g/cm$^3$; $\rho_{bit}$=0.97 g/cm$^3$; $\rho_{anth}$=1.1 g/cm$^3$). The results shown in Figures 2.13 and 2.14 indicate that the reduced viscosities increased in a fairly linear manner up to about 24% by volume (30 wt%) coal concentration. Above this concentration there was a drastic increase in the reduced viscosity. It also seemed that the reduced viscosity versus volume concentration data produced basically the same result independent of which oil was used to make the slurries.

The linear portions of Figures 2.13 and 2.14 ($\phi$<25%) were correlated with the Einstein model equation (1.14). The slope of the line through the data is the constant, K, in equation (1.14). The results of this correlation are given in Table 2.5. With the exception of the bitumen slurry at 50°C in the cooling mode, the values for K all

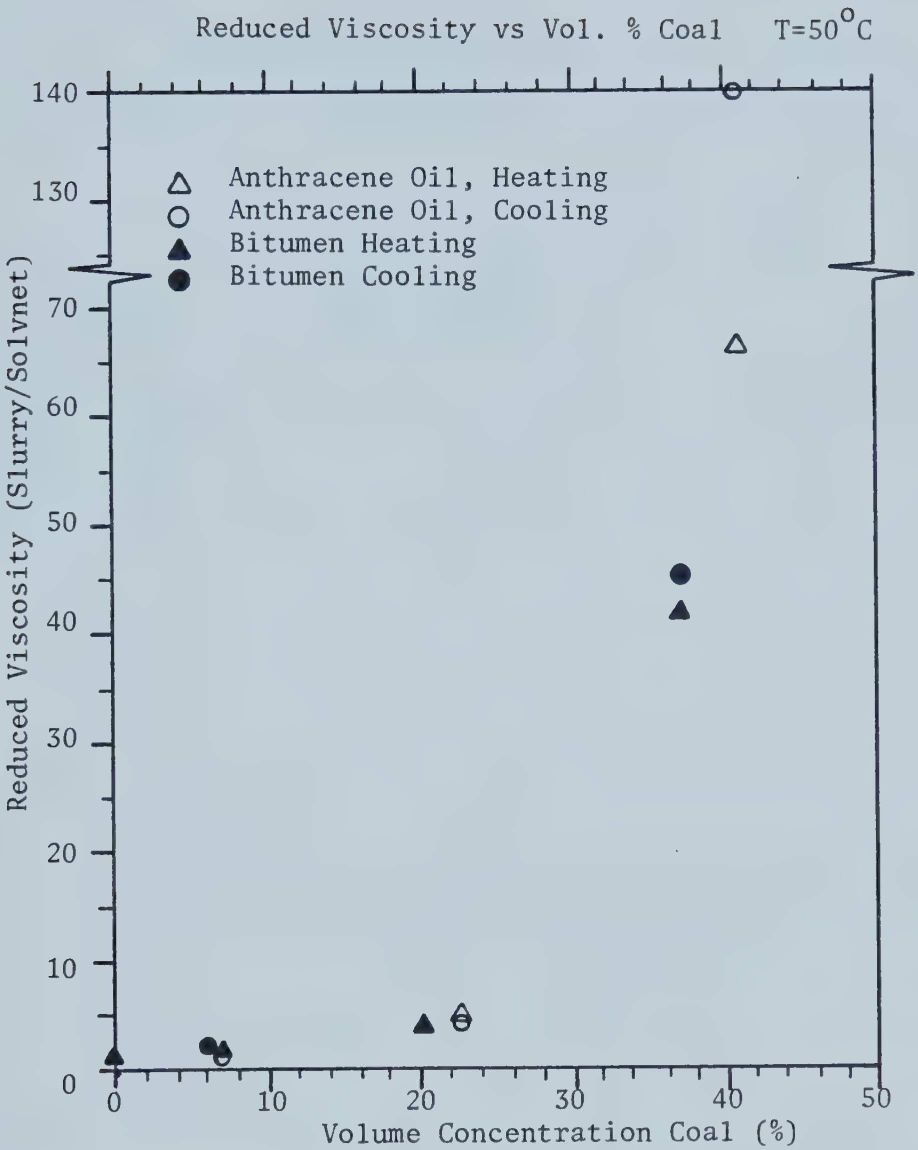



Figure 2.13 Reduced Viscosity versus Coal Concentration Plot-Low Temperature

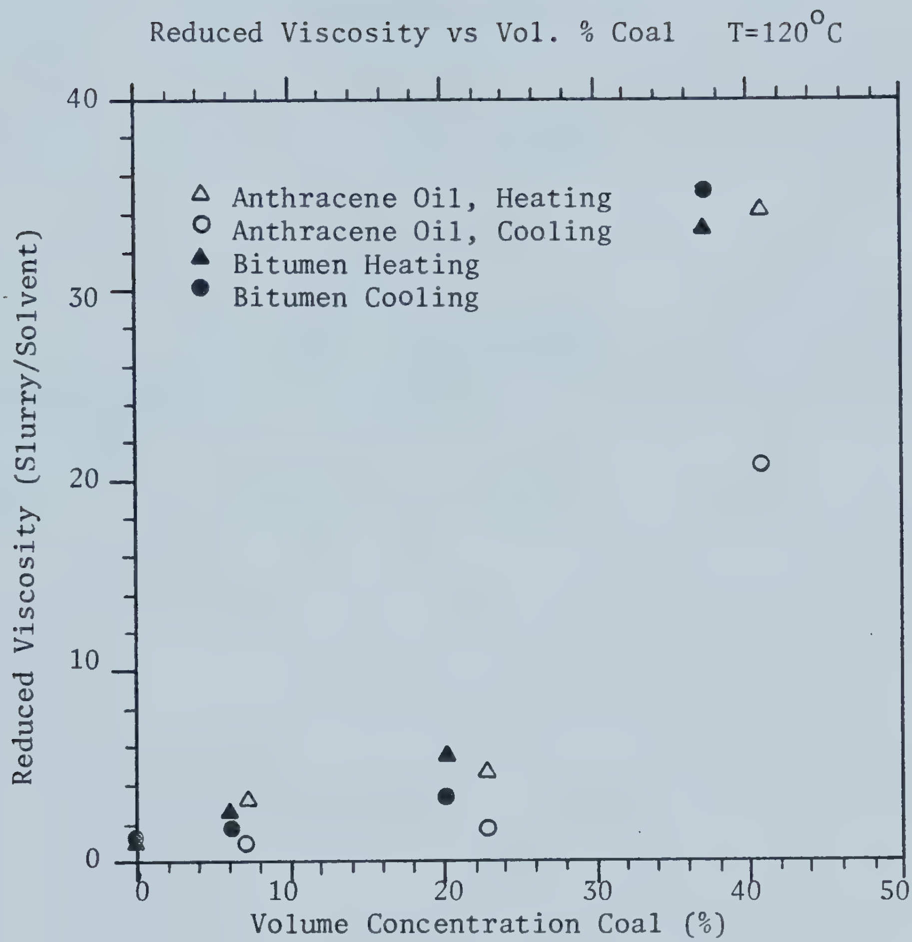



Figure 2.14 Reduced Viscosity versus Coal Concentration Plot-High Temperature

Table 2.5 VALUES OF K FOR REDUCED VISCOSITY VERSUS COAL CONCENTRATION DATA - (<25%)

K - VALUES

| Oil | Heating | | Cooling | |
| --- | --- | --- | --- | --- |
| | T = 50°C | T = 120°C | T = 50°C | T = 120°C |
| Anthracene | 16.3 | 11.8 | 15.4 | 10.3 |
| Bitumen | 15.0 | 15.3 | 26.8 | 12.5 |

fell in a fairly close range between 10.0 and 16.0, irrespective of the solvent used. These values for K are high as compared with others reported [19]. Equation (1.14) was derived for non-interacting, uniform spherical particles. The large values for K found in this work may have been due to the irregular shape of the coal particles. Chemical interactions between the particles and between the particles and the fluid may also have contributed to the large values for K.

In Figures 2.13 and 2.14, for coal concentrations above 30% by volume, the reduced viscosity of the slurries increased with an almost infinite rate. This behaviour was most probably due to increased energy dissipation from coal particle collisions as compared to mainly fluid shearing at lower coal concentrations. This effect was observed in previous work [39, 47].

Finally, the apparent viscosities of the slurries studied in this work were compared with the reported viscosities of other common fluids. This was done in order to acquire a better practical "feel" for the numbers that were dealt with in this study. The results of this comparison are shown in Figure 2.15 where the apparent viscosity versus temperature is plotted for bitumen, anthracene oil, 30 wt% coal-bitumen and 50 wt% coal-anthracene oil slurries. This figure showed that the apparent viscosities of the slurries studied here were at the high end of the viscosity scale, as compared with crude and fuel oils.

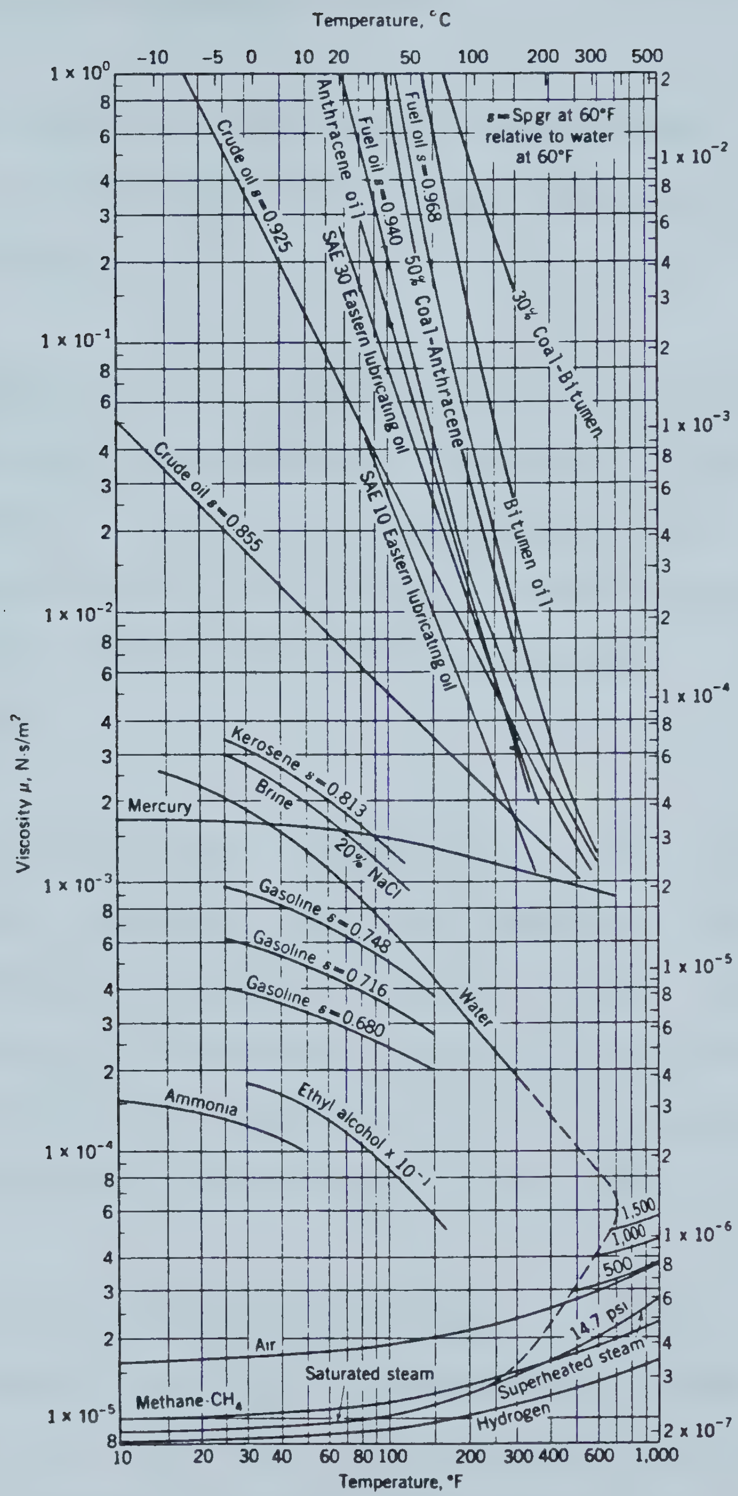



Figure 2.15 Absolute Viscosity of Common Fluids

## 3. Conclusions and Recommentations

From this work the following conclusions may be drawn regarding the viscous behaviour of coal-anthracene oil and coal-bitumen slurries:

1. Increasing coal concentration imposed a shear thinning (pseudoplastic) tendency on the flow curves for both types of slurry tested. This pseudoplastic effect did not become significant, however, until the coal concentration was 50% by weight.

2. The temperature dependence of the apparent slurry viscosity may be modelled using the activation energy concept. The activation energy of flow was determined by the solvent and was generally independent of coal concentration for the two solvents used in this work.

3. The concentration dependence of reduced slurry viscosity, for coal concentrations under 30%, could be correlated using Einstein's equation. The effect of coal concentration on reduced viscosity was greater than that typically reported in the literature.

A recommendation for future work would be to repeat the experiments in a sealed vessel (eliminating solvent evaporation) to confirm the second conclusion.

REFERENCES


1. Ackerman, N.L., Shen, H.T., "Rheological Characteristics of Solid-Liquid Mixtures", AIChE Journal, 25, #2, March, 1979.

2. Anderson, P.C., et. al., "Rheology of Coal-Oil Dispersions", Powder Technology 32 pp. 45-54, 1982.

3. Astarita, G., Marrucci, G., Principles of Non-Newtonian Fluid Mechanics, McGraw-Hill, London, 1974.

4. Bagnold, R.A., "Experiments on Gravity-Free Dispersion of Large Spheres in a Newtonian Fluid Under Shear", Proc. Roy. Soc. of London, A-225, pp. 49-63, 1954.

5. Berkowitz, N., et. al., "The Pipeline Flow of Coal-in-Oil Suspensions", Canadian Journal of Chem. Eng., 41, pp. 116-121, June, 1963.

6. Bhattachmarya, S.N., Barro, L., "Flow Characteristics of Coal-Oil Slurries", Proc. The AIS. I.M.M. Conf. New Zealand, 1980.

7. Bird, R.B., Stewart, W.E., and Lightfoot, E.N., Transport Phenomena, John Wiley, New York, 1960.

8. Castillo, C., "Rheological Study of Coal Slurries", M.S. Thesis, University of California, Berkeley, June, 1978.

9. Castillo, C., Williams, M.C., "Rheology of Very Concentrated Coal Suspensions", Chem. Eng. Commun., Vol. 3, pp. 529-547, 1979.

10. Chong, J.S., et. al., "Rheology of Concentrated Suspensions", Jour. of Applied Polymer Sci., 15, pp. 2007-2021, 1971.

11. Coleman, B.D., et. al., Viscometric Flows of Non-Newtonian Fluids, Springer-Verlag, New York, 1966.

12. Cross, M.M., "Kinetic Interpretation of Non-Newtonian Flow", Jour. of Colloid and Interface Sci., 33, #1, May, 1970.

13. Droege, J.W., Chauhan, S.P., "Viscous Properties of Coal-SRC Mixtures", EPRI Report #RP-779-2, 1978.

14. Droege, J.W., et. al., "Thermophysical Properties of Preheater Slurries", Proc. 16th IECEC, 1981.

15. Droege, J.W., et. al., "Viscosity at Elevated Temperature and Pressure of Coal Derived Liquids", Proc. 7th Symp. Thermophysical Prop., Gaithersburg, Maryland, May 10-12, 1977, ASME.

16. E.D.S. Coal Liquefaction Process Development, Phase IIIA, Final Technical Progress Report, Feb. 1978.

17. Elliott, D.E., Gliddon, B.J., "Hydraulic Transport of Coal at High Concentrations" proc. 1st International Conf. on the Hydraulic Transport of Solids in Pipes, paper G2, Sept. 1-4, 1970.

18. Florez, M.R., "Rheology of Exxon Donor Solvent (EDS) Process Coal Liquefaction Streams", AIChE Fall Annual Meeting, New Orleans, L.A., Nov. 8-12, 1981.

19. Franke, N.A., Acrivos, A., "On the Viscosity of a Concentrated Suspension of Solid Sphere", Chem. Eng. Sci., 22, pp. 847-853, 1967.

20. Glasstone, S., Laidler, K.J., Eyring, H., Theory of Rate Processes, McGraw-Hill, New York, 1941.

21. Govier, G.W., Aziz, K., The Flow of Complex Mixtures in Pipes, Van Norstrand-Reinhold, New York, 1972.

22. Hanks, R.W., "A New Viscometer for Determining the Effect of Particle Distributions and Concentration on Slurry Rheology", Proc. 7th International Technical Conf. on Slurry Transportation.

23. Herczynski, R., Pienkowska, I., "Effective Viscosity of Suspension", Archives of Mechanics, 27, pp. 201-217, Warszawa, 1975.

24. Hershey, D., Transport Analysis, Plenum Press, New York, 1974.

25. Jeffery, D.J., Acrivos, A., "The Rheological Properties of Suspensions of Rigid Particles", AIChE. Journal, 22, #3, May, 1976.

26. Kreusing, U., Franke, F.H., "Investigations on the Flow and Pumping Behaviour of Coal-Oil Mixtures with Particular Reference to the Injection of a Coal-Oil-Slurry into the Blast Furnace", Sixth International Conferene on the Hydraulic Transport of Solids in Pipes, Paper C2, Canterbury, U.K., Sept. 26-28, 1979.

27. Lee, D.D., et. al., "Characterization of Coal-Solvent Slurries and H-Coal PDV Reactor Effluent at High Temperatures and Pressures, IECEC, 1981.

28. Lord, N.W., et. al., Coal-Oil Mixtures Technology, Ann Arbor Sci. Publishers, An Arbor, Michigan, 1982.

29. McNesse, L.E., ORNL-5487, Fossil Energy Program Quarterly Progress Report for Period Ending Sept. 30, 1978.

30. McNesse, L.E., ORNL-5550, Fossil Energy Program Quarterly Progress Report for Period Ending March 31, 1979.

31. McNesse, L.E., ORNL-5574, Fossil Energy Program Quarterly Progress Report for Period Ending June 30, 1979.

32. McNesse, L.E., ORNL-5612, Fossil Energy Program Quarterly Progress Report for Period Ending Sept. 30, 1979.

33. McNesse, L.E., ORNL-5671, Fossil Energy Program Quarterly Progress Report for Period Ending June 30, 1980.

34. McNesse, L.E., ORNL-7573, Fossil Energy Program Quarterly Progress Report for September 30, 1980.

35. Metzner, A.B., Reed, J.C., "Flow of Non-Newtonian Fluids-Correlation of the Laminar, Transition, and Turbulent Flow Regions" AIChE Journal, 1, 4, 1955.

36. Moreland, C., "Viscosity of Suspensions of Coal in Mineral Oil" Canadian Journal of Chem. Eng., 41, pp. 24-28, Feb. 1963.

37. Munro, J.M., et. al., "A Characterization of the Rheological Properties of Coal-Fuel Oil Slurries", AIChE Journal, 25, #2, March, 1979.

38. Onischar, M., et. al., "Rheology and Transportation Characteristics of A Coal Gasification Feed Slurry", Proceedings: Fifth International Technical Conference on Slurry Transportation, Lake Tahoe, Nevada, March 26-28, 1981.

39. Ozum, B., et. al., "Viscosity of Coal-Bitumen and Coal-Anthracene Oil Slurries", proc. 6th Symposium on Eng. Appl. to Mech., Calgary, Alberta, June 7, 1982.

40. Ozum, B., "Rheological Character of Coal Slurries", A.R.C. Internal Report, July 15, 1981.

41. Ozum, B., du Plessis, M.P., "Review of Heat Transfer and the Design of Heat Exchanges for Coal Slurries", A.R.C. Internal Report, Feb. 1982.

42. Sabhapathy, P., "Rheological Properties of Coal Solvent Slurries", Internal Report to A.R.C., March, 1982.

43. Schlichting, H., Boundary Layer Theory, 7th Ed., McGraw-Hill, New York, 1979.

44. Schowalter, W.R., "Some Consequences of Suspension Models for Nonviscometric Flow", Jour. of Non-Newtonian Fluid Mech., 5, 1979.

45. Shaheen, E.I., "Rheological Study of Viscosities and Pipeline Flow of Concentrated Slurries", Powder Tech., 5, pp. 245-256, 1971/72.

46. Simua, R., "A Treatment of Viscosity of Concentrated Suspensions", Jour. of Applied Physics, 23, #9, Sept. 1952.

47. Stefurak, G., "Coal-Oil Slurry Viscosities" Work Term Report, Dept. of Mech. Eng., Univ. of Waterloo, August, 1981.

48. Thomas, D.G., "Transport Characteristics of Suspension: VIII. A Note on the Viscosity of Newtonian Suspensions of Uniform Spherical Particles", Jour. of Colloidal Sci., 20, pp. 267-277, 1965.

49. Thurgood, J.R., "The Rheological Characterization of Coal Liquefaction Preheater Slurries", AIChE Journal, 28, #1, January, 1982.

50. Van Wazer, J.R., et. al., Viscosity and Flow Measurement, A Laboratory hand Book of Rheology", Inter Science Publishers, New York, 1963.

51. Vasalos, I.A., et. al., "A Characterization of the Rheological Properties of Coal-Fuel Oil Slurries", AIChE Journal, 25, #2, March, 1979.

52. Wasp, E.J., et. al., Solid-Liquid Flow-Slurry Pipeline Transportation, Trans Tech Publications, Clasthal, Germany, 1977.

53. Yamagatta, Y., et. al., "Rheological Study of Viscosities and Pipeline Flow of Coal-Oil Mixtures", Proc. 7th International Conf. on the Hydraulic Transport of Solids in Pipes, paper G1, Sendai, Japan, Nov. 4-6, 1980.

# APPENDIX A

# COAL PARTICLE SIZE DISTRIBUTION

# APPENDIX A

## PARTICLE SIZE ANALYSIS

PROGRAM VERSION: 2.5
LAST UPDATE: March 4, 1982

JOB NUMBER: 1845

SAMPLE NUMBER: COA

SAMPLE WEIGHT: 127.50 g.

WET SIEVING:
- Initial Weight: 127.50 g.
- +325 Mesh Fraction: 92.49 g.
- -325 Mesh Fraction: 33.68 g.
- Weight Loss 1.33 g. ( 1.04)

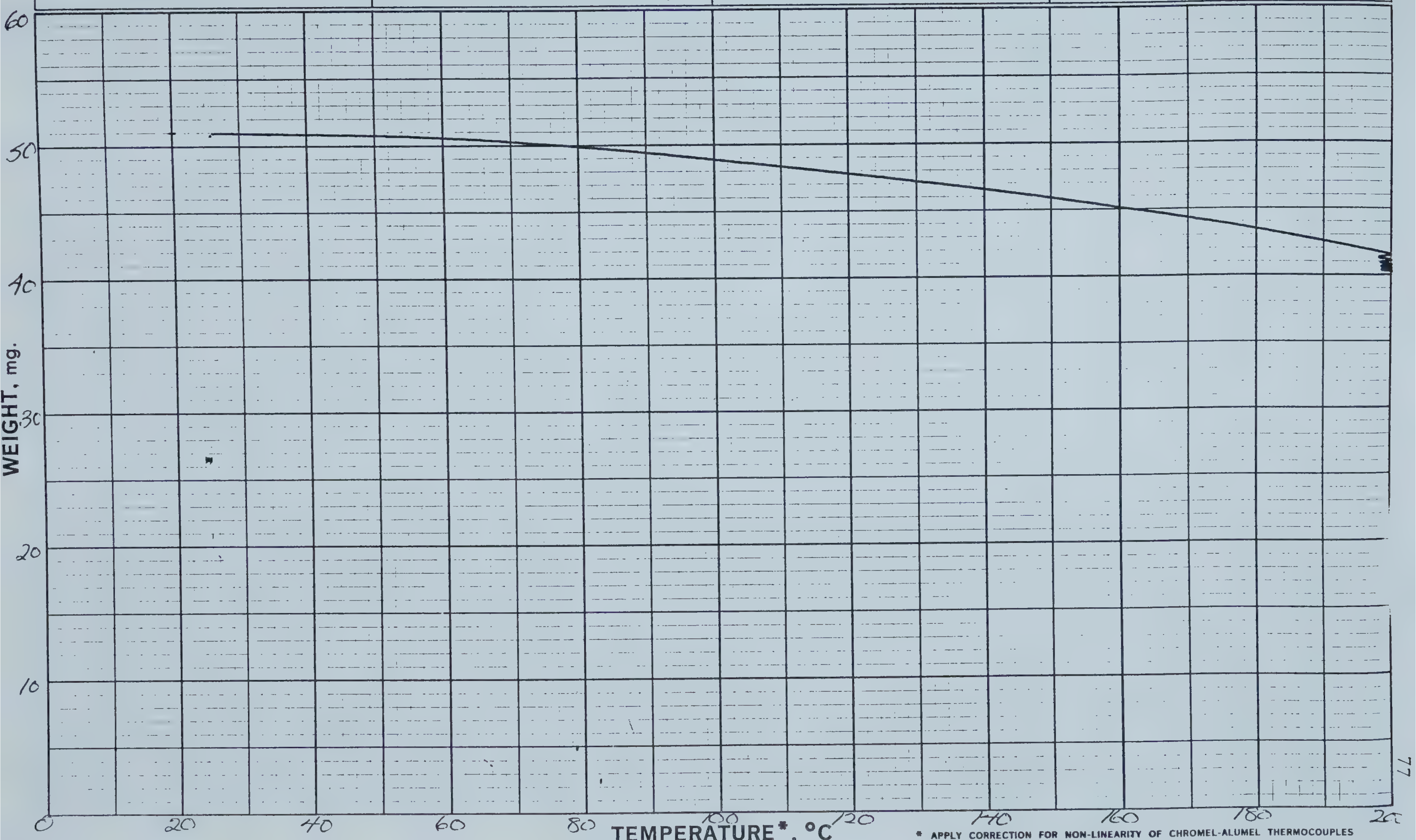
DRY SIEVING:
- Initial Weight: 92.49 g.
- +400 Mesh Fraction: 84.98 g.
- -400 Mesh Fraction: 7.59 g.
- Weight Loss: -0.08 g. (-0.09%)

| PARTICLE SIZE mesh | phi | microns | FRACTIONAL WEIGHT | CUMULATIVE WEIGHT | FRACTIONAL PERCENT | CUMULATIVE PERCENT |
|---|---|---|---|---|---|---|
| 18 | 0.00 | 1000.0 | 0.00 | 0.00 | 0.00 | 0.00 |
| 25 | 0.50 | 710.0 | 0.00 | 0.00 | 0.00 | 0.00 |
| 35 | 1.00 | 500.0 | 0.00 | 0.00 | 0.00 | 0.00 |
| 45 | 1.50 | 350.0 | 0.02 | 0.02 | 0.02 | 0.02 |
| 60 | 2.00 | 250.0 | 0.00 | 0.02 | 0.00 | 0.02 |
| 80 | 2.50 | 177.0 | 0.00 | 0.02 | 0.00 | 0.02 |
| 120 | 3.00 | 125.0 | 13.32 | 13.34 | 10.55 | 10.57 |
| 170 | 3.50 | 88.0 | 28.10 | 41.44 | 22.26 | 32.82 |
| 230 | 4.00 | 62.5 | 14.61 | 56.05 | 11.57 | 44.40 |
| 325 | 4.50 | 44.0 | 23.24 | 79.29 | 18.41 | 62.80 |
| 400 | 4.75 | 31.0 | 5.69 | 84.98 | 4.51 | 67.31 |
| | 5.30 | 25.4 | 7.71 | 112.82 | 6.10 | 89.37 |
| | 5.63 | 20.2 | 4.10 | 116.93 | 3.25 | 92.62 |
| | 5.97 | 16.0 | 2.65 | 119.58 | 2.10 | 94.72 |
| | 6.30 | 12.7 | 1.99 | 121.57 | 1.58 | 96.29 |
| | 6.63 | 10.1 | 1.49 | 123.06 | 1.18 | 97.47 |
| | 6.97 | 8.0 | 1.12 | 124.18 | 0.89 | 98.36 |
| | 7.30 | 6.3 | 0.75 | 124.92 | 0.59 | 98.95 |
| | 7.63 | 5.0 | 0.54 | 125.46 | 0.43 | 99.38 |
| | 7.97 | 4.0 | 0.41 | 125.88 | 0.33 | 99.70 |
| | 8.30 | 3.2 | 0.25 | 126.13 | 0.20 | 99.90 |
| | 8.63 | 2.5 | 0.12 | 126.25 | 0.10 | 100.00 |

## APPENDIX B

## TGA CURVES FOR COAL-BITUMEN SLURRIES

| SAMPLE: G. KOVACIK, ARC BITUMEN | X-AXIS | Y-AXIS | RUN NO. ____ DATE May/82 |
|---|---|---|---|
| | TEMP. SCALE 20 °C/inch | SCALE 10 mg./inch | OPERATOR CM |
| | SHIFT 0 inch | ~~(SCALE SETTING × 2)~~ | HEATING RATE 2 °C/min. |
| | | | ATM. $N_2$ |
| SIZE ≃51.0 mg. | TIME SCALE (ALT.) Temp | SUPPRESSION 0 mg. | TIME CONSTANT 1 sec. |




* APPLY CORRECTION FOR NON-LINEARITY OF CHROMEL-ALUMEL THERMOCOUPLES

SAMPLE: 10% bit. coal.

SIZE ~51.0 mg.

| X-AXIS | Y-AXIS |
|---|---|
| TEMP. SCALE 20 °C/inch | SCALE 10 mg./inch |
| SHIFT 0 inch | ~~(SCALE SETTING X 2)~~ |
| TIME SCALE (ALT.) Temp | SUPPRESSION 0 mg. |

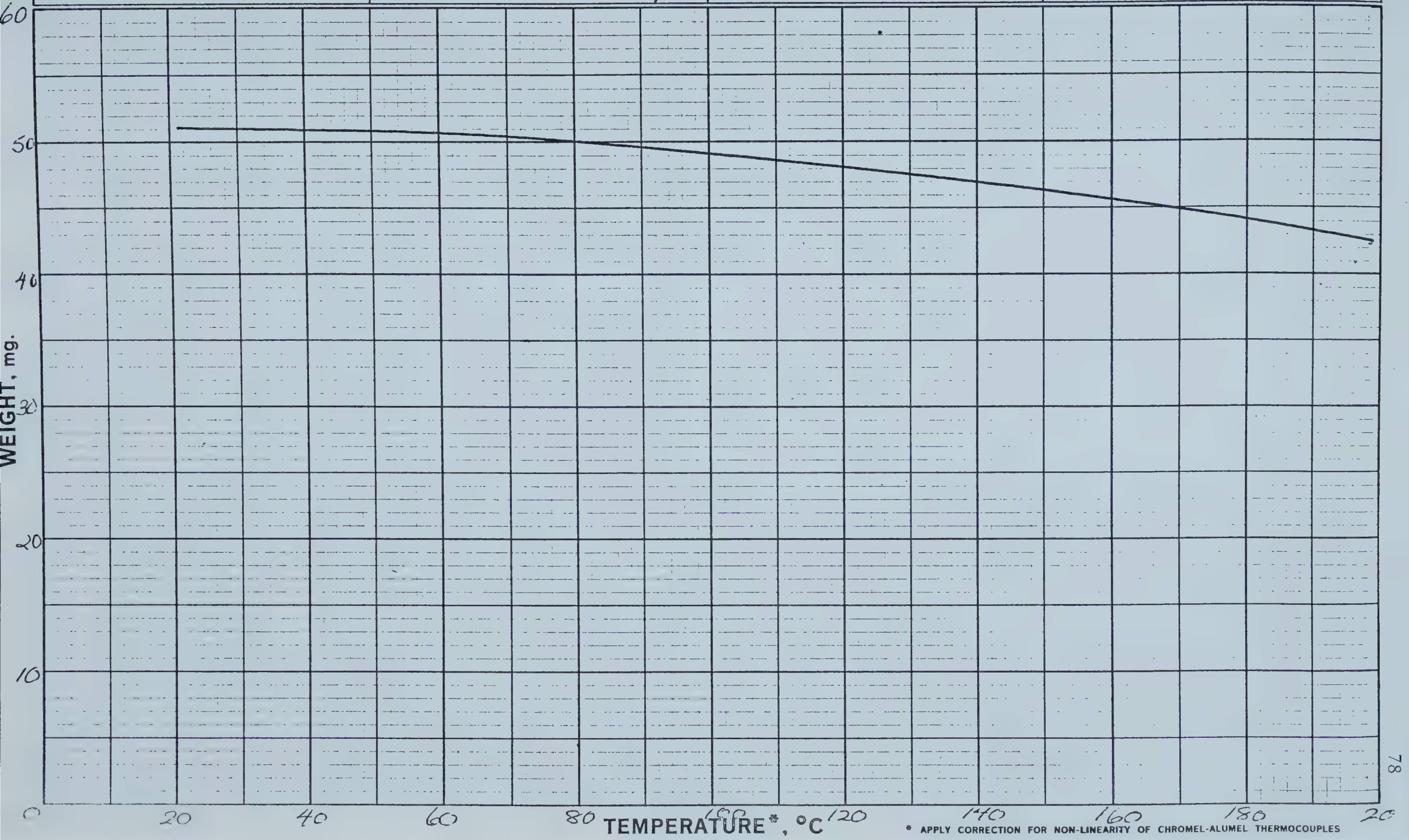
RUN NO. ____ DATE May/82

OPERATOR CM

HEATING RATE 2 °C/min.

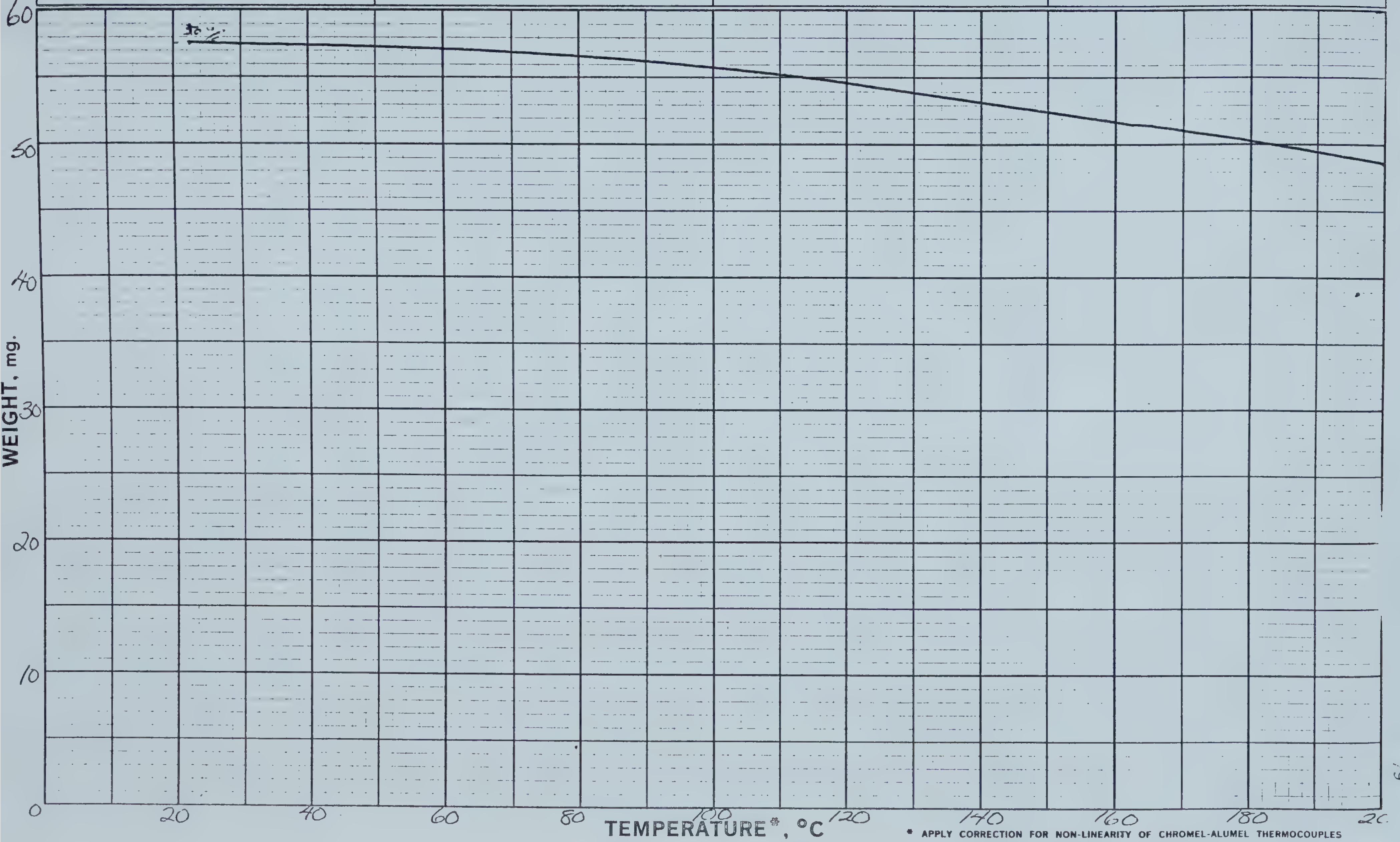
ATM. $N_2$

TIME CONSTANT 1 sec.




* APPLY CORRECTION FOR NON-LINEARITY OF CHROMEL-ALUMEL THERMOCOUPLES

| SAMPLE: 30% bit. coal | X-AXIS | Y-AXIS | RUN NO. ___ DATE May 18 |
|---|---|---|---|
| | TEMP. SCALE 20 °C/inch | SCALE 10 mg./inch | OPERATOR CM |
| | SHIFT 0 inch | ~~(SCALE SETTING X 2)~~ | HEATING RATE 2 °C/min. |
| | | | ATM. $N_2$ |
| SIZE ≃57.5 mg. | TIME SCALE (ALT.) Temp | SUPPRESSION 0 mg. | TIME CONSTANT 1 sec. |




* APPLY CORRECTION FOR NON-LINEARITY OF CHROMEL-ALUMEL THERMOCOUPLES

# APPENDIX C

# DATA

# APPENDIX C - DATA

## LEGEND

In this appendix the raw data is sorted by oil, coal concentration and heating and cooling modes. The data is arranged in six columns. The first column on the left is the run number; the second column is the coal concentration by weight, the third column is the temperature in degrees celsius; the forth column is the shear rate; the fifth column is the shear stress; the sixth and last column is the apparent viscosity in Pa.s.

# ANTHRACENE OIL - HEATING

| | | | | | |
|---|---|---|---|---|---|
| 1 | 0.0 | 24.4 | 17.549999 | 8.500800 | 0.484376 |
| 1 | 0.0 | 24.4 | 35.099998 | 15.842401 | 0.451350 |
| 1 | 0.0 | 24.4 | 52.650002 | 23.570402 | 0.447681 |
| 1 | 0.0 | 24.4 | 70.199997 | 30.912001 | 0.440342 |
| 1 | 0.0 | 24.4 | 87.750000 | 38.639999 | 0.440342 |
| 1 | 0.0 | 24.4 | 105.300003 | 45.981602 | 0.436672 |
| 1 | 0.0 | 24.4 | 122.849991 | 53.323204 | 0.434051 |
| 1 | 0.0 | 24.4 | 140.399994 | 60.664803 | 0.432086 |
| 1 | 0.0 | 24.4 | 157.949997 | 68.006401 | 0.430557 |
| 1 | 0.0 | 24.4 | 175.500000 | 74.961609 | 0.427132 |
| 2 | 0.0 | 30.0 | 29.249998 | 5.796000 | 0.198154 |
| 2 | 0.0 | 30.0 | 58.499996 | 11.205601 | 0.191549 |
| 2 | 0.0 | 30.0 | 87.750000 | 17.001600 | 0.193750 |
| 2 | 0.0 | 30.0 | 116.999992 | 22.797600 | 0.194851 |
| 2 | 0.0 | 30.0 | 146.250000 | 28.593599 | 0.195512 |
| 2 | 0.0 | 30.0 | 175.500000 | 34.389603 | 0.195952 |
| 2 | 0.0 | 30.0 | 204.749985 | 40.185600 | 0.196267 |
| 2 | 0.0 | 30.0 | 233.999985 | 45.595200 | 0.194851 |
| 2 | 0.0 | 30.0 | 263.250000 | 52.164001 | 0.198154 |
| 2 | 0.0 | 30.0 | 292.500000 | 56.800804 | 0.194191 |
| 3 | 0.0 | 36.4 | 29.249998 | 3.187800 | 0.108985 |
| 3 | 0.0 | 36.4 | 58.499996 | 5.796000 | 0.099077 |
| 3 | 0.0 | 36.4 | 87.750000 | 8.404201 | 0.095774 |
| 3 | 0.0 | 36.4 | 116.999992 | 11.012400 | 0.094123 |
| 3 | 0.0 | 36.4 | 146.250000 | 13.910400 | 0.095114 |
| 3 | 0.0 | 36.4 | 175.500000 | 16.518600 | 0.094123 |
| 3 | 0.0 | 36.4 | 204.749985 | 19.416601 | 0.094831 |
| 3 | 0.0 | 36.4 | 233.999985 | 22.024799 | 0.094123 |
| 3 | 0.0 | 36.4 | 263.250000 | 24.922800 | 0.094674 |
| 3 | 0.0 | 36.4 | 292.500000 | 27.531000 | 0.094123 |
| 4 | 0.0 | 44.9 | 58.499996 | 2.898000 | 0.049538 |
| 4 | 0.0 | 44.9 | 116.999992 | 5.554500 | 0.047474 |
| 4 | 0.0 | 44.9 | 175.500000 | 8.211000 | 0.046786 |
| 4 | 0.0 | 44.9 | 233.999985 | 10.867500 | 0.046442 |
| 4 | 0.0 | 44.9 | 292.500000 | 13.524000 | 0.046236 |
| 4 | 0.0 | 44.9 | 351.000000 | 16.422001 | 0.046786 |
| 4 | 0.0 | 44.9 | 409.499969 | 19.078501 | 0.046590 |
| 4 | 0.0 | 44.9 | 467.999969 | 22.459501 | 0.047990 |
| 4 | 0.0 | 44.9 | 526.500000 | 24.633001 | 0.046786 |
| 4 | 0.0 | 44.9 | 585.000000 | 31.878000 | 0.054492 |
| 5 | 0.0 | 53.3 | 70.199997 | 1.738800 | 0.024769 |
| 5 | 0.0 | 53.3 | 140.399994 | 3.284400 | 0.023393 |
| 5 | 0.0 | 53.3 | 210.600006 | 5.023200 | 0.023852 |
| 5 | 0.0 | 53.3 | 280.799988 | 6.568800 | 0.023393 |
| 5 | 0.0 | 53.3 | 351.000000 | 8.307600 | 0.023668 |
| 5 | 0.0 | 53.3 | 421.200012 | 9.853200 | 0.023393 |
| 5 | 0.0 | 53.3 | 491.399963 | 11.785201 | 0.023983 |
| 5 | 0.0 | 53.3 | 561.599976 | 13.330801 | 0.023737 |
| 5 | 0.0 | 53.3 | 631.799988 | 15.069600 | 0.023852 |
| 5 | 0.0 | 53.3 | 702.000000 | 16.808401 | 0.023944 |
| 6 | 0.0 | 61.3 | 70.199997 | 1.159200 | 0.016513 |
| 6 | 0.0 | 61.3 | 140.399994 | 2.221800 | 0.015825 |
| 6 | 0.0 | 61.3 | 210.600006 | 3.284400 | 0.015595 |
| 6 | 0.0 | 61.3 | 280.799988 | 4.347000 | 0.015481 |
| 6 | 0.0 | 61.3 | 351.000000 | 5.409600 | 0.015412 |
| 6 | 0.0 | 61.3 | 421.200012 | 6.472200 | 0.015366 |
| 6 | 0.0 | 61.3 | 491.399963 | 7.631400 | 0.015530 |
| 6 | 0.0 | 61.3 | 561.599976 | 8.790601 | 0.015653 |
| 6 | 0.0 | 61.3 | 631.799988 | 9.949800 | 0.015748 |
| 6 | 0.0 | 61.3 | 702.000000 | 11.109000 | 0.015825 |
| 7 | 0.0 | 71.6 | 81.899994 | 0.772800 | 0.009436 |

| | | | | | |
|---|---|---|---|---|---|
| 7 | 0.0 | 71.6 | 163.799988 | 1.642200 | 0.010026 |
| 7 | 0.0 | 71.6 | 245.699997 | 2.415000 | 0.009829 |
| 7 | 0.0 | 71.6 | 327.599976 | 3.187800 | 0.009731 |
| 7 | 0.0 | 71.6 | 409.500000 | 3.960600 | 0.009672 |
| 7 | 0.0 | 71.6 | 491.399994 | 4.830000 | 0.009829 |
| 7 | 0.0 | 71.6 | 573.299988 | 5.699400 | 0.009941 |
| 7 | 0.0 | 71.6 | 655.199951 | 6.568800 | 0.010026 |
| 7 | 0.0 | 71.6 | 737.099976 | 7.534800 | 0.010222 |
| 7 | 0.0 | 71.6 | 819.000000 | 8.404201 | 0.010262 |
| 8 | 0.0 | 81.2 | 81.899994 | 0.579600 | 0.007077 |
| 8 | 0.0 | 81.2 | 163.799988 | 1.086750 | 0.006635 |
| 8 | 0.0 | 81.2 | 245.699997 | 1.666350 | 0.006782 |
| 8 | 0.0 | 81.2 | 327.599976 | 2.245950 | 0.006856 |
| 8 | 0.0 | 81.2 | 409.500000 | 2.825550 | 0.006900 |
| 8 | 0.0 | 81.2 | 491.399994 | 3.405150 | 0.006929 |
| 8 | 0.0 | 81.2 | 573.299988 | 4.057200 | 0.007077 |
| 8 | 0.0 | 81.2 | 655.199951 | 4.709250 | 0.007188 |
| 8 | 0.0 | 81.2 | 737.099976 | 5.288850 | 0.007175 |
| 8 | 0.0 | 81.2 | 819.000000 | 4.564350 | 0.005573 |
| 9 | 0.0 | 90.4 | 93.599998 | 0.652050 | 0.006966 |
| 9 | 0.0 | 90.4 | 187.199997 | 1.086750 | 0.005805 |
| 9 | 0.0 | 90.4 | 280.799988 | 1.593900 | 0.005676 |
| 9 | 0.0 | 90.4 | 374.399994 | 2.101050 | 0.005612 |
| 9 | 0.0 | 90.4 | 468.000000 | 2.608200 | 0.005573 |
| 9 | 0.0 | 90.4 | 561.599976 | 3.187800 | 0.005676 |
| 9 | 0.0 | 90.4 | 655.199951 | 3.694950 | 0.005639 |
| 9 | 0.0 | 90.4 | 748.799988 | 4.274550 | 0.005709 |
| 9 | 0.0 | 90.4 | 842.399963 | 4.854150 | 0.005762 |
| 9 | 0.0 | 90.4 | 936.000000 | 5.506200 | 0.005883 |
| 10 | 0.0 | 101.1 | 105.299995 | 0.652050 | 0.006192 |
| 10 | 0.0 | 101.1 | 210.599991 | 1.014300 | 0.004816 |
| 10 | 0.0 | 101.1 | 315.899994 | 1.449000 | 0.004587 |
| 10 | 0.0 | 101.1 | 421.199982 | 1.883700 | 0.004472 |
| 10 | 0.0 | 101.1 | 473.849976 | 2.173500 | 0.004587 |
| 10 | 0.0 | 101.1 | 526.500000 | 2.390850 | 0.004541 |
| 10 | 0.0 | 101.1 | 631.799988 | 2.898000 | 0.004587 |
| 10 | 0.0 | 101.1 | 684.449951 | 3.187800 | 0.004657 |
| 10 | 0.0 | 101.1 | 737.099976 | 3.405150 | 0.004620 |
| 10 | 0.0 | 101.1 | 842.399963 | 3.984750 | 0.004730 |
| 11 | 0.0 | 109.6 | 116.999992 | 0.743820 | 0.006357 |
| 11 | 0.0 | 109.6 | 175.500000 | 0.946680 | 0.005394 |
| 11 | 0.0 | 109.6 | 233.999985 | 1.149540 | 0.004913 |
| 11 | 0.0 | 109.6 | 351.000000 | 1.487640 | 0.004238 |
| 11 | 0.0 | 109.6 | 467.999969 | 1.893360 | 0.004046 |
| 11 | 0.0 | 109.6 | 526.500000 | 2.163840 | 0.004110 |
| 11 | 0.0 | 109.6 | 585.000000 | 2.366700 | 0.004046 |
| 11 | 0.0 | 109.6 | 643.500000 | 2.569560 | 0.003993 |
| 11 | 0.0 | 109.6 | 702.000000 | 2.840040 | 0.004046 |
| 11 | 0.0 | 109.6 | 760.499939 | 3.110520 | 0.004090 |
| 12 | 0.0 | 111.3 | 116.999992 | 0.608580 | 0.005202 |
| 12 | 0.0 | 111.3 | 233.999985 | 1.081920 | 0.004624 |
| 12 | 0.0 | 111.3 | 351.000000 | 1.622880 | 0.004624 |
| 12 | 0.0 | 111.3 | 409.499969 | 1.825740 | 0.004458 |
| 12 | 0.0 | 111.3 | 467.999969 | 2.096220 | 0.004479 |
| 12 | 0.0 | 111.3 | 585.000000 | 2.637180 | 0.004508 |
| 12 | 0.0 | 111.3 | 643.500000 | 2.907660 | 0.004519 |
| 12 | 0.0 | 111.3 | 702.000000 | 3.178140 | 0.004527 |
| 12 | 0.0 | 111.3 | 760.499939 | 3.448620 | 0.004535 |
| 12 | 0.0 | 111.3 | 818.999939 | 3.786720 | 0.004624 |
| 13 | 0.0 | 131.4 | 58.499996 | 0.241500 | 0.004128 |
| 13 | 0.0 | 131.4 | 116.999992 | 0.338100 | 0.002890 |

| | | | | | |
|---|---|---|---|---|---|
| 13 | 0.0 | 131.4 | 175.500000 | 0.579600 | 0.003303 |
| 13 | 0.0 | 131.4 | 233.999985 | 0.676200 | 0.002890 |
| 13 | 0.0 | 131.4 | 292.500000 | 0.821100 | 0.002807 |
| 13 | 0.0 | 131.4 | 351.000000 | 1.014300 | 0.002890 |
| 13 | 0.0 | 131.4 | 409.499969 | 1.159200 | 0.002831 |
| 13 | 0.0 | 131.4 | 467.999969 | 1.352400 | 0.002890 |
| 13 | 0.0 | 131.4 | 526.500000 | 1.545600 | 0.002936 |
| 13 | 0.0 | 131.4 | 561.599976 | 1.738800 | 0.003096 |
| 14 | 0.0 | 150.4 | 116.999992 | 0.241500 | 0.002064 |
| 14 | 0.0 | 150.4 | 233.999985 | 0.579600 | 0.002477 |
| 14 | 0.0 | 150.4 | 351.000000 | 0.869400 | 0.002477 |
| 14 | 0.0 | 150.4 | 467.999969 | 1.207500 | 0.002580 |
| 14 | 0.0 | 150.4 | 585.000000 | 1.738800 | 0.002972 |
| 14 | 0.0 | 150.4 | 702.000000 | 2.318400 | 0.003303 |
| 14 | 0.0 | 150.4 | 818.999939 | 3.042900 | 0.003715 |
| 14 | 0.0 | 150.4 | 935.999939 | 3.767400 | 0.004025 |
| 14 | 0.0 | 150.4 | 1053.000000 | 4.636800 | 0.004403 |
| 14 | 0.0 | 150.4 | 1170.000000 | 5.554500 | 0.004747 |

10% w/w COAL-ANTHRACENE OIL - HEATING

| | | | | | |
|---|---|---|---|---|---|
| 17 | 10.0 | 21.5 | 7.200000 | 12.995000 | 1.804861 |
| 17 | 10.0 | 21.5 | 14.400001 | 24.295000 | 1.687153 |
| 17 | 10.0 | 21.5 | 21.600000 | 35.595001 | 1.647917 |
| 17 | 10.0 | 21.5 | 28.800001 | 46.895000 | 1.628299 |
| 17 | 10.0 | 21.5 | 36.000000 | 59.324997 | 1.647917 |
| 17 | 10.0 | 21.5 | 43.200001 | 71.190002 | 1.647917 |
| 17 | 10.0 | 21.5 | 50.399998 | 81.925003 | 1.625496 |
| 17 | 10.0 | 21.5 | 57.600002 | 96.050003 | 1.667535 |
| 17 | 10.0 | 21.5 | 64.799995 | 107.350006 | 1.656636 |
| 17 | 10.0 | 21.5 | 69.840004 | 113.000000 | 1.617984 |
| 18 | 10.0 | 28.8 | 18.000000 | 8.475000 | 0.470833 |
| 18 | 10.0 | 28.8 | 36.000000 | 15.820000 | 0.439444 |
| 18 | 10.0 | 28.8 | 54.000000 | 23.164999 | 0.428981 |
| 18 | 10.0 | 28.8 | 72.000000 | 29.944998 | 0.415903 |
| 18 | 10.0 | 28.8 | 90.000000 | 37.290001 | 0.414333 |
| 18 | 10.0 | 28.8 | 108.000000 | 45.200001 | 0.418519 |
| 18 | 10.0 | 28.8 | 125.999992 | 52.544998 | 0.417024 |
| 18 | 10.0 | 28.8 | 144.000000 | 59.324997 | 0.411979 |
| 18 | 10.0 | 28.8 | 161.999985 | 66.104996 | 0.408056 |
| 18 | 10.0 | 28.8 | 180.000000 | 73.449997 | 0.408056 |
| 19 | 10.0 | 36.5 | 45.000000 | 6.215000 | 0.138111 |
| 19 | 10.0 | 36.5 | 90.000000 | 11.865000 | 0.131833 |
| 19 | 10.0 | 36.5 | 135.000000 | 18.645000 | 0.138111 |
| 19 | 10.0 | 36.5 | 180.000000 | 23.730000 | 0.131833 |
| 19 | 10.0 | 36.5 | 225.000000 | 30.510002 | 0.135600 |
| 19 | 10.0 | 36.5 | 270.000000 | 37.855000 | 0.140204 |
| 19 | 10.0 | 36.5 | 315.000000 | 45.200001 | 0.143492 |
| 19 | 10.0 | 36.5 | 360.000000 | 51.415001 | 0.142819 |
| 19 | 10.0 | 36.5 | 404.999969 | 59.889996 | 0.147877 |
| 19 | 10.0 | 36.5 | 450.000000 | 66.104996 | 0.146900 |
| 20 | 10.0 | 47.0 | 45.000000 | 2.825000 | 0.062778 |
| 20 | 10.0 | 47.0 | 90.000000 | 5.085000 | 0.056500 |
| 20 | 10.0 | 47.0 | 135.000000 | 7.627501 | 0.056500 |
| 20 | 10.0 | 47.0 | 180.000000 | 10.170000 | 0.056500 |
| 20 | 10.0 | 47.0 | 225.000000 | 13.277499 | 0.059011 |
| 20 | 10.0 | 47.0 | 270.000000 | 15.820000 | 0.058593 |
| 20 | 10.0 | 47.0 | 315.000000 | 18.927500 | 0.060087 |
| 20 | 10.0 | 47.0 | 360.000000 | 21.469999 | 0.059639 |
| 20 | 10.0 | 47.0 | 404.999969 | 24.295000 | 0.059988 |
| 20 | 10.0 | 47.0 | 450.000000 | 27.120001 | 0.060267 |
| 21 | 10.0 | 48.0 | 45.000000 | 2.034000 | 0.045200 |
| 21 | 10.0 | 48.0 | 90.000000 | 4.294000 | 0.047711 |
| 21 | 10.0 | 48.0 | 135.000000 | 6.780000 | 0.050222 |
| 21 | 10.0 | 48.0 | 180.000000 | 9.492000 | 0.052733 |
| 21 | 10.0 | 48.0 | 225.000000 | 11.978000 | 0.053236 |
| 21 | 10.0 | 48.0 | 270.000000 | 14.690000 | 0.054407 |
| 21 | 10.0 | 48.0 | 315.000000 | 17.401999 | 0.055244 |
| 21 | 10.0 | 48.0 | 360.000000 | 20.114000 | 0.055872 |
| 21 | 10.0 | 48.0 | 404.999969 | 23.051998 | 0.056919 |
| 21 | 10.0 | 48.0 | 450.000000 | 25.764000 | 0.057253 |
| 22 | 10.0 | 59.8 | 45.000000 | 1.525500 | 0.033900 |
| 22 | 10.0 | 59.8 | 90.000000 | 2.712000 | 0.030133 |
| 22 | 10.0 | 59.8 | 135.000000 | 4.068000 | 0.030133 |
| 22 | 10.0 | 59.8 | 180.000000 | 5.424000 | 0.030133 |
| 22 | 10.0 | 59.8 | 225.000000 | 6.780000 | 0.030133 |
| 22 | 10.0 | 59.8 | 270.000000 | 8.305500 | 0.030761 |
| 22 | 10.0 | 59.8 | 315.000000 | 9.830999 | 0.031210 |
| 22 | 10.0 | 59.8 | 360.000000 | 11.356500 | 0.031546 |
| 22 | 10.0 | 59.8 | 404.999969 | 12.882000 | 0.031807 |
| 22 | 10.0 | 59.8 | 450.000000 | 14.746500 | 0.032770 |
| 23 | 10.0 | 68.5 | 45.000000 | 0.565000 | 0.012556 |

| | | | | | |
|---|---|---|---|---|---|
| 23 | 10.0 | 68.5 | 90.000000 | 1.356000 | 0.015067 |
| 23 | 10.0 | 68.5 | 135.000000 | 2.034000 | 0.015067 |
| 23 | 10.0 | 68.5 | 157.500000 | 2.486000 | 0.015784 |
| 23 | 10.0 | 68.5 | 180.000000 | 2.938000 | 0.016322 |
| 23 | 10.0 | 68.5 | 202.499985 | 3.277000 | 0.016183 |
| 23 | 10.0 | 68.5 | 225.000000 | 3.729000 | 0.016573 |
| 23 | 10.0 | 68.5 | 247.500015 | 4.181000 | 0.016893 |
| 23 | 10.0 | 68.5 | 270.000000 | 4.633000 | 0.017159 |
| 23 | 10.0 | 68.5 | 292.500000 | 5.085000 | 0.017385 |
| 24 | 10.0 | 79.5 | 22.500000 | 0.452000 | 0.020089 |
| 24 | 10.0 | 79.5 | 45.000000 | 0.678000 | 0.015067 |
| 24 | 10.0 | 79.5 | 67.500000 | 0.904000 | 0.013393 |
| 24 | 10.0 | 79.5 | 90.000000 | 1.017000 | 0.011300 |
| 24 | 10.0 | 79.5 | 112.500000 | 1.356000 | 0.012053 |
| 24 | 10.0 | 79.5 | 135.000000 | 1.582000 | 0.011719 |
| 24 | 10.0 | 79.5 | 157.500000 | 1.808000 | 0.011479 |
| 24 | 10.0 | 79.5 | 171.000000 | 1.921000 | 0.011234 |
| 24 | 10.0 | 79.5 | 180.000000 | 2.147000 | 0.011928 |
| 24 | 10.0 | 79.5 | 198.000000 | 2.373000 | 0.011985 |
| 25 | 10.0 | 104.8 | 22.500000 | 0.169500 | 0.007533 |
| 25 | 10.0 | 104.8 | 45.000000 | 0.282500 | 0.006278 |
| 25 | 10.0 | 104.8 | 67.500000 | 0.395500 | 0.005859 |
| 25 | 10.0 | 104.8 | 90.000000 | 0.508500 | 0.005650 |
| 25 | 10.0 | 104.8 | 112.500000 | 0.791000 | 0.007031 |
| 25 | 10.0 | 104.8 | 135.000000 | 1.073500 | 0.007952 |
| 25 | 10.0 | 104.8 | 157.500000 | 1.412500 | 0.008968 |
| 25 | 10.0 | 104.8 | 180.000000 | 1.751500 | 0.009731 |
| 25 | 10.0 | 104.8 | 202.499985 | 2.090500 | 0.010323 |
| 25 | 10.0 | 104.8 | 225.000000 | 2.486000 | 0.011049 |
| 26 | 10.0 | 124.6 | 45.000000 | 0.226000 | 0.005022 |
| 26 | 10.0 | 124.6 | 67.500000 | 0.339000 | 0.005022 |
| 26 | 10.0 | 124.6 | 90.000000 | 0.452000 | 0.005022 |
| 26 | 10.0 | 124.6 | 112.500000 | 0.621500 | 0.005524 |
| 26 | 10.0 | 124.6 | 123.750008 | 0.791000 | 0.006392 |
| 26 | 10.0 | 124.6 | 135.000000 | 0.904000 | 0.006696 |
| 26 | 10.0 | 124.6 | 157.500000 | 1.130000 | 0.007175 |
| 26 | 10.0 | 124.6 | 180.000000 | 1.412500 | 0.007847 |
| 26 | 10.0 | 124.6 | 202.499985 | 1.695000 | 0.008370 |
| 26 | 10.0 | 124.6 | 225.000000 | 1.977500 | 0.008789 |
| 27 | 10.0 | 148.4 | 22.500000 | 0.056500 | 0.002511 |
| 27 | 10.0 | 148.4 | 45.000000 | 0.113000 | 0.002511 |
| 27 | 10.0 | 148.4 | 67.500000 | 0.226000 | 0.003348 |
| 27 | 10.0 | 148.4 | 90.000000 | 0.339000 | 0.003767 |
| 27 | 10.0 | 148.4 | 112.500000 | 0.508500 | 0.004520 |
| 27 | 10.0 | 148.4 | 135.000000 | 0.678000 | 0.005022 |
| 27 | 10.0 | 148.4 | 157.500000 | 0.904000 | 0.005740 |
| 27 | 10.0 | 148.4 | 180.000000 | 1.130000 | 0.006278 |
| 27 | 10.0 | 148.4 | 202.499985 | 1.356000 | 0.006696 |
| 27 | 10.0 | 148.4 | 225.000000 | 1.582000 | 0.007031 |

30% w/w COAL-ANTHRACENE OIL - HEATING

| | | | | | |
|---|---|---|---|---|---|
| 29 | 30.0 | 23.3 | 0.450000 | 12.429999 | 27.622219 |
| 29 | 30.0 | 23.3 | 0.900000 | 21.469999 | 23.855555 |
| 29 | 30.0 | 23.3 | 1.350000 | 29.944998 | 22.181479 |
| 29 | 30.0 | 23.3 | 1.800000 | 37.855000 | 21.030554 |
| 29 | 30.0 | 23.3 | 2.250000 | 45.764999 | 20.340000 |
| 29 | 30.0 | 23.3 | 2.700000 | 51.980000 | 19.251852 |
| 29 | 30.0 | 23.3 | 3.150000 | 58.759998 | 18.653969 |
| 29 | 30.0 | 23.3 | 3.600000 | 64.410004 | 17.891666 |
| 29 | 30.0 | 23.3 | 4.050000 | 71.754997 | 17.717285 |
| 29 | 30.0 | 23.3 | 4.500000 | 76.840004 | 17.075556 |
| 30 | 30.0 | 37.4 | 15.750001 | 9.040000 | 0.573968 |
| 30 | 30.0 | 37.4 | 31.500002 | 18.080000 | 0.573968 |
| 30 | 30.0 | 37.4 | 47.250000 | 25.990000 | 0.550053 |
| 30 | 30.0 | 37.4 | 63.000004 | 34.465000 | 0.547063 |
| 30 | 30.0 | 37.4 | 78.750000 | 42.375000 | 0.538095 |
| 30 | 30.0 | 37.4 | 94.500000 | 49.154999 | 0.520159 |
| 30 | 30.0 | 37.4 | 110.249992 | 55.935001 | 0.507347 |
| 30 | 30.0 | 37.4 | 126.000008 | 63.279999 | 0.502222 |
| 30 | 30.0 | 37.4 | 141.749985 | 68.930000 | 0.486279 |
| 30 | 30.0 | 37.4 | 157.500000 | 74.580002 | 0.473524 |
| 31 | 30.0 | 45.3 | 33.750000 | 7.910000 | 0.234370 |
| 31 | 30.0 | 45.3 | 67.500000 | 15.820000 | 0.234370 |
| 31 | 30.0 | 45.3 | 101.250000 | 23.730000 | 0.234370 |
| 31 | 30.0 | 45.3 | 135.000000 | 30.510002 | 0.226000 |
| 31 | 30.0 | 45.3 | 168.750000 | 37.855000 | 0.224326 |
| 31 | 30.0 | 45.3 | 202.500000 | 44.635002 | 0.220420 |
| 31 | 30.0 | 45.3 | 236.249985 | 51.980000 | 0.220021 |
| 31 | 30.0 | 45.3 | 270.000000 | 58.759998 | 0.217630 |
| 31 | 30.0 | 45.3 | 303.749969 | 65.540001 | 0.215770 |
| 31 | 30.0 | 45.3 | 337.500000 | 72.320000 | 0.214281 |
| 32 | 30.0 | 52.5 | 33.750000 | 4.068000 | 0.120533 |
| 32 | 30.0 | 52.5 | 67.500000 | 7.797000 | 0.115511 |
| 32 | 30.0 | 52.5 | 101.250000 | 11.865000 | 0.117185 |
| 32 | 30.0 | 52.5 | 135.000000 | 15.933000 | 0.118022 |
| 32 | 30.0 | 52.5 | 168.750000 | 20.000998 | 0.118524 |
| 32 | 30.0 | 52.5 | 202.500000 | 24.747002 | 0.122207 |
| 32 | 30.0 | 52.5 | 236.249985 | 27.798000 | 0.117664 |
| 32 | 30.0 | 52.5 | 270.000000 | 32.205002 | 0.119278 |
| 32 | 30.0 | 52.5 | 303.749969 | 36.272999 | 0.119417 |
| 32 | 30.0 | 52.5 | 337.500000 | 40.001995 | 0.118524 |
| 33 | 30.0 | 62.8 | 36.000000 | 2.034000 | 0.056500 |
| 33 | 30.0 | 62.8 | 72.000000 | 3.842000 | 0.053361 |
| 33 | 30.0 | 62.8 | 108.000000 | 5.650000 | 0.052315 |
| 33 | 30.0 | 62.8 | 144.000000 | 7.458000 | 0.051792 |
| 33 | 30.0 | 62.8 | 180.000000 | 9.266000 | 0.051478 |
| 33 | 30.0 | 62.8 | 216.000000 | 11.074000 | 0.051269 |
| 33 | 30.0 | 62.8 | 251.999985 | 13.108000 | 0.052016 |
| 33 | 30.0 | 62.8 | 288.000000 | 14.916000 | 0.051792 |
| 33 | 30.0 | 62.8 | 323.999969 | 16.950001 | 0.052315 |
| 33 | 30.0 | 62.8 | 360.000000 | 18.757999 | 0.052106 |
| 34 | 30.0 | 72.0 | 36.000000 | 1.271250 | 0.035312 |
| 34 | 30.0 | 72.0 | 72.000000 | 2.260000 | 0.031389 |
| 34 | 30.0 | 72.0 | 108.000000 | 3.390000 | 0.031389 |
| 34 | 30.0 | 72.0 | 144.000000 | 4.520000 | 0.031389 |
| 34 | 30.0 | 72.0 | 180.000000 | 5.650000 | 0.031389 |
| 34 | 30.0 | 72.0 | 216.000000 | 6.780000 | 0.031389 |
| 34 | 30.0 | 72.0 | 251.999985 | 8.051250 | 0.031949 |
| 34 | 30.0 | 72.0 | 288.000000 | 9.322500 | 0.032370 |
| 34 | 30.0 | 72.0 | 323.999969 | 10.735000 | 0.033133 |
| 34 | 30.0 | 72.0 | 360.000000 | 12.147500 | 0.033743 |
| 35 | 30.0 | 79.5 | 36.000000 | 0.904000 | 0.025111 |

| | | | | | |
|---|---|---|---|---|---|
| 35 | 30.0 | 79.5 | 72.000000 | 1.808000 | 0.025111 |
| 35 | 30.0 | 79.5 | 108.000000 | 2.599000 | 0.024065 |
| 35 | 30.0 | 79.5 | 144.000000 | 3.503000 | 0.024326 |
| 35 | 30.0 | 79.5 | 180.000000 | 4.407000 | 0.024483 |
| 35 | 30.0 | 79.5 | 216.000000 | 5.424000 | 0.025111 |
| 35 | 30.0 | 79.5 | 251.999985 | 6.328000 | 0.025111 |
| 35 | 30.0 | 79.5 | 288.000000 | 7.345000 | 0.025503 |
| 35 | 30.0 | 79.5 | 323.999969 | 8.475000 | 0.026157 |
| 35 | 30.0 | 79.5 | 360.000000 | 9.605000 | 0.026681 |
| 36 | 30.0 | 89.8 | 45.000000 | 0.904000 | 0.020089 |
| 36 | 30.0 | 89.8 | 90.000000 | 1.695000 | 0.018833 |
| 36 | 30.0 | 89.8 | 135.000000 | 2.486000 | 0.018415 |
| 36 | 30.0 | 89.8 | 180.000000 | 3.390000 | 0.018833 |
| 36 | 30.0 | 89.8 | 202.499985 | 3.842000 | 0.018973 |
| 36 | 30.0 | 89.8 | 225.000000 | 4.294000 | 0.019084 |
| 36 | 30.0 | 89.8 | 270.000000 | 5.311000 | 0.019670 |
| 36 | 30.0 | 89.8 | 292.500000 | 5.876000 | 0.020089 |
| 36 | 30.0 | 89.8 | 315.000000 | 6.441000 | 0.020448 |
| 36 | 30.0 | 89.8 | 337.500000 | 7.006001 | 0.020759 |
| 37 | 30.0 | 109.0 | 36.000000 | 0.678000 | 0.018833 |
| 37 | 30.0 | 109.0 | 72.000000 | 1.101750 | 0.015302 |
| 37 | 30.0 | 109.0 | 108.000000 | 1.610250 | 0.014910 |
| 37 | 30.0 | 109.0 | 125.999992 | 1.864500 | 0.014798 |
| 37 | 30.0 | 109.0 | 144.000000 | 2.118750 | 0.014714 |
| 37 | 30.0 | 109.0 | 161.999985 | 2.373000 | 0.014648 |
| 37 | 30.0 | 109.0 | 180.000000 | 2.627250 | 0.014596 |
| 37 | 30.0 | 109.0 | 198.000015 | 2.881500 | 0.014553 |
| 37 | 30.0 | 109.0 | 216.000000 | 3.135750 | 0.014517 |
| 37 | 30.0 | 109.0 | 234.000000 | 3.474750 | 0.014849 |
| 38 | 30.0 | 126.8 | 36.000000 | 0.508500 | 0.014125 |
| 38 | 30.0 | 126.8 | 54.000000 | 0.678000 | 0.012556 |
| 38 | 30.0 | 126.8 | 72.000000 | 0.847500 | 0.011771 |
| 38 | 30.0 | 126.8 | 90.000000 | 1.017000 | 0.011300 |
| 38 | 30.0 | 126.8 | 108.000000 | 1.186500 | 0.010986 |
| 38 | 30.0 | 126.8 | 125.999992 | 1.356000 | 0.010762 |
| 38 | 30.0 | 126.8 | 144.000000 | 1.610250 | 0.011182 |
| 38 | 30.0 | 126.8 | 161.999985 | 1.779750 | 0.010986 |
| 38 | 30.0 | 126.8 | 180.000000 | 2.034000 | 0.011300 |
| 38 | 30.0 | 126.8 | 198.000015 | 2.373000 | 0.011985 |
| 39 | 30.0 | 136.6 | 31.500002 | 0.452000 | 0.014349 |
| 39 | 30.0 | 136.6 | 47.250000 | 0.621500 | 0.013153 |
| 39 | 30.0 | 136.6 | 63.000004 | 0.734500 | 0.011659 |
| 39 | 30.0 | 136.6 | 78.750000 | 0.847500 | 0.010762 |
| 39 | 30.0 | 136.6 | 94.500000 | 0.960500 | 0.010164 |
| 39 | 30.0 | 136.6 | 110.249992 | 1.073500 | 0.009737 |
| 39 | 30.0 | 136.6 | 126.000008 | 1.243000 | 0.009865 |
| 39 | 30.0 | 136.6 | 141.749985 | 1.469000 | 0.010363 |
| 39 | 30.0 | 136.6 | 157.500000 | 1.638500 | 0.010403 |
| 39 | 30.0 | 136.6 | 173.250015 | 1.921000 | 0.011088 |
| 40 | 30.0 | 146.6 | 31.500002 | 0.339000 | 0.010762 |
| 40 | 30.0 | 146.6 | 63.000004 | 0.508500 | 0.008071 |
| 40 | 30.0 | 146.6 | 78.750000 | 0.621500 | 0.007892 |
| 40 | 30.0 | 146.6 | 94.500000 | 0.678000 | 0.007175 |
| 40 | 30.0 | 146.6 | 110.249992 | 0.791000 | 0.007175 |
| 40 | 30.0 | 146.6 | 126.000008 | 0.904000 | 0.007175 |
| 40 | 30.0 | 146.6 | 141.749985 | 1.130000 | 0.007972 |
| 40 | 30.0 | 146.6 | 157.500000 | 1.299500 | 0.008251 |
| 40 | 30.0 | 146.6 | 173.250015 | 1.582000 | 0.009131 |
| 40 | 30.0 | 146.6 | 189.000000 | 1.864500 | 0.009865 |

50% w/w COAL-ANTHRACENE OIL - HEATING

| | | | | | |
|---|---|---|---|---|---|
| 46 | 50.0 | 36.3 | 0.900000 | 14.690000 | 16.322222 |
| 46 | 50.0 | 36.3 | 1.800000 | 26.554998 | 14.752776 |
| 46 | 50.0 | 36.3 | 2.700000 | 38.420002 | 14.229630 |
| 46 | 50.0 | 36.3 | 3.600000 | 49.154999 | 13.654166 |
| 46 | 50.0 | 36.3 | 4.500000 | 59.889996 | 13.308887 |
| 46 | 50.0 | 36.3 | 5.400000 | 70.060005 | 12.974074 |
| 46 | 50.0 | 36.3 | 6.300000 | 80.229996 | 12.734921 |
| 46 | 50.0 | 36.3 | 7.200000 | 89.834999 | 12.477082 |
| 46 | 50.0 | 36.3 | 8.099999 | 98.875000 | 12.206791 |
| 46 | 50.0 | 36.3 | 9.000000 | 107.350006 | 11.927778 |
| 47 | 50.0 | 44.5 | 1.350000 | 13.560000 | 10.044445 |
| 47 | 50.0 | 44.5 | 2.700000 | 24.295000 | 8.998148 |
| 47 | 50.0 | 44.5 | 4.050000 | 34.465000 | 8.509876 |
| 47 | 50.0 | 44.5 | 5.400000 | 44.070000 | 8.161111 |
| 47 | 50.0 | 44.5 | 6.750000 | 53.109997 | 7.868148 |
| 47 | 50.0 | 44.5 | 8.100000 | 61.020004 | 7.533333 |
| 47 | 50.0 | 44.5 | 9.450000 | 68.930000 | 7.294180 |
| 47 | 50.0 | 44.5 | 10.800000 | 77.404999 | 7.167130 |
| 47 | 50.0 | 44.5 | 12.150000 | 85.315002 | 7.021811 |
| 47 | 50.0 | 44.5 | 13.500000 | 91.529999 | 6.780000 |
| 48 | 50.0 | 54.2 | 6.750000 | 14.125000 | 2.092592 |
| 48 | 50.0 | 54.2 | 13.500001 | 25.424999 | 1.883333 |
| 48 | 50.0 | 54.2 | 20.250000 | 35.595001 | 1.757778 |
| 48 | 50.0 | 54.2 | 27.000002 | 45.200001 | 1.674074 |
| 48 | 50.0 | 54.2 | 33.750000 | 54.805000 | 1.623852 |
| 48 | 50.0 | 54.2 | 40.500000 | 63.844997 | 1.576420 |
| 48 | 50.0 | 54.2 | 47.249996 | 72.320000 | 1.530582 |
| 48 | 50.0 | 54.2 | 54.000004 | 80.794998 | 1.496204 |
| 48 | 50.0 | 54.2 | 60.749996 | 88.705002 | 1.460165 |
| 48 | 50.0 | 54.2 | 67.500000 | 94.919998 | 1.406222 |
| 49 | 50.0 | 64.2 | 18.000000 | 12.429999 | 0.690556 |
| 49 | 50.0 | 64.2 | 36.000000 | 23.164999 | 0.643472 |
| 49 | 50.0 | 64.2 | 54.000000 | 32.770000 | 0.606852 |
| 49 | 50.0 | 64.2 | 72.000000 | 41.810001 | 0.580694 |
| 49 | 50.0 | 64.2 | 90.000000 | 50.285000 | 0.558722 |
| 49 | 50.0 | 64.2 | 108.000000 | 58.759998 | 0.544074 |
| 49 | 50.0 | 64.2 | 125.999992 | 67.235008 | 0.533611 |
| 49 | 50.0 | 64.2 | 144.000000 | 75.144997 | 0.521840 |
| 49 | 50.0 | 64.2 | 161.999985 | 83.620003 | 0.516173 |
| 49 | 50.0 | 64.2 | 180.000000 | 90.400002 | 0.502222 |
| 50 | 50.0 | 74.3 | 33.750000 | 13.560000 | 0.401778 |
| 50 | 50.0 | 74.3 | 67.500000 | 25.990000 | 0.385037 |
| 50 | 50.0 | 74.3 | 101.250000 | 37.290001 | 0.368296 |
| 50 | 50.0 | 74.3 | 135.000000 | 46.895000 | 0.347370 |
| 50 | 50.0 | 74.3 | 168.750000 | 57.064999 | 0.338163 |
| 50 | 50.0 | 74.3 | 202.500000 | 66.104996 | 0.326444 |
| 50 | 50.0 | 74.3 | 236.249985 | 74.580002 | 0.315683 |
| 50 | 50.0 | 74.3 | 270.000000 | 83.055000 | 0.307611 |
| 50 | 50.0 | 74.3 | 303.749969 | 88.139999 | 0.290173 |
| 50 | 50.0 | 74.3 | 337.500000 | 93.790001 | 0.277896 |
| 51 | 50.0 | 84.3 | 22.500000 | 6.780000 | 0.301333 |
| 51 | 50.0 | 84.3 | 45.000000 | 11.865000 | 0.263667 |
| 51 | 50.0 | 84.3 | 67.500000 | 18.080000 | 0.267852 |
| 51 | 50.0 | 84.3 | 90.000000 | 23.164999 | 0.257389 |
| 51 | 50.0 | 84.3 | 112.500000 | 28.250000 | 0.251111 |
| 51 | 50.0 | 84.3 | 135.000000 | 33.334999 | 0.246926 |
| 51 | 50.0 | 84.3 | 180.000000 | 41.810001 | 0.232278 |
| 51 | 50.0 | 84.3 | 202.499985 | 46.329998 | 0.228790 |
| 51 | 50.0 | 84.3 | 225.000000 | 50.285000 | 0.223489 |
| 51 | 50.0 | 84.3 | 270.000000 | 58.195000 | 0.215537 |
| 52 | 50.0 | 93.6 | 27.000002 | 4.972000 | 0.184148 |

| | | | | | |
|---|---|---|---|---|---|
| 52 | 50.0 | 93.6 | 54.000004 | 9.040000 | 0.167407 |
| 52 | 50.0 | 93.6 | 81.000000 | 13.108000 | 0.161827 |
| 52 | 50.0 | 93.6 | 108.000008 | 16.724001 | 0.154852 |
| 52 | 50.0 | 93.6 | 135.000000 | 20.792000 | 0.154015 |
| 52 | 50.0 | 93.6 | 162.000000 | 24.408003 | 0.150667 |
| 52 | 50.0 | 93.6 | 188.999985 | 28.024002 | 0.148275 |
| 52 | 50.0 | 93.6 | 216.000015 | 31.640001 | 0.146481 |
| 52 | 50.0 | 93.6 | 242.999985 | 35.256001 | 0.145086 |
| 52 | 50.0 | 93.6 | 270.000000 | 38.872002 | 0.143970 |
| 53 | 50.0 | 112.6 | 36.000000 | 5.085000 | 0.141250 |
| 53 | 50.0 | 112.6 | 72.000000 | 9.153001 | 0.127125 |
| 53 | 50.0 | 112.6 | 108.000000 | 13.221000 | 0.122417 |
| 53 | 50.0 | 112.6 | 144.000000 | 17.628000 | 0.122417 |
| 53 | 50.0 | 112.6 | 180.000000 | 22.035000 | 0.122417 |
| 53 | 50.0 | 112.6 | 216.000000 | 26.441999 | 0.122417 |
| 53 | 50.0 | 112.6 | 251.999985 | 31.188000 | 0.123762 |
| 53 | 50.0 | 112.6 | 288.000000 | 35.256001 | 0.122417 |
| 53 | 50.0 | 112.6 | 323.999969 | 39.662998 | 0.122417 |
| 53 | 50.0 | 112.6 | 360.000000 | 43.730995 | 0.121475 |
| 54 | 50.0 | 123.2 | 18.000000 | 1.977500 | 0.109861 |
| 54 | 50.0 | 123.2 | 36.000000 | 3.361750 | 0.093382 |
| 54 | 50.0 | 123.2 | 54.000000 | 4.746000 | 0.087889 |
| 54 | 50.0 | 123.2 | 72.000000 | 6.130250 | 0.085142 |
| 54 | 50.0 | 123.2 | 90.000000 | 7.712250 | 0.085692 |
| 54 | 50.0 | 123.2 | 108.000000 | 9.096500 | 0.084227 |
| 54 | 50.0 | 123.2 | 125.999992 | 10.480749 | 0.083181 |
| 54 | 50.0 | 123.2 | 144.000000 | 11.865001 | 0.082396 |
| 54 | 50.0 | 123.2 | 161.999985 | 13.447001 | 0.083006 |
| 54 | 50.0 | 123.2 | 180.000000 | 15.029000 | 0.083494 |
| 55 | 50.0 | 132.0 | 31.500002 | 3.164000 | 0.100444 |
| 55 | 50.0 | 132.0 | 63.000004 | 6.130250 | 0.097306 |
| 55 | 50.0 | 132.0 | 94.500000 | 8.898749 | 0.094167 |
| 55 | 50.0 | 132.0 | 126.000008 | 11.667249 | 0.092597 |
| 55 | 50.0 | 132.0 | 157.500000 | 14.633500 | 0.092911 |
| 55 | 50.0 | 132.0 | 189.000000 | 17.599751 | 0.093120 |
| 55 | 50.0 | 132.0 | 220.499985 | 20.961498 | 0.095063 |
| 55 | 50.0 | 132.0 | 252.000015 | 24.125500 | 0.095736 |
| 55 | 50.0 | 132.0 | 283.499969 | 27.091749 | 0.095562 |
| 55 | 50.0 | 132.0 | 315.000000 | 30.058001 | 0.095422 |
| 56 | 50.0 | 144.8 | 27.000002 | 3.390000 | 0.125556 |
| 56 | 50.0 | 144.8 | 54.000004 | 6.102000 | 0.113000 |
| 56 | 50.0 | 144.8 | 81.000000 | 8.475000 | 0.104630 |
| 56 | 50.0 | 144.8 | 108.000008 | 10.678500 | 0.098875 |
| 56 | 50.0 | 144.8 | 135.000000 | 12.712501 | 0.094167 |
| 56 | 50.0 | 144.8 | 162.000000 | 14.915999 | 0.092074 |
| 56 | 50.0 | 144.8 | 188.999985 | 16.780500 | 0.088786 |
| 56 | 50.0 | 144.8 | 216.000015 | 18.645000 | 0.086319 |
| 56 | 50.0 | 144.8 | 242.999985 | 20.509501 | 0.084401 |
| 56 | 50.0 | 144.8 | 270.000000 | 22.204500 | 0.082239 |
| 57 | 50.0 | 144.8 | 27.000002 | 2.203500 | 0.081611 |
| 57 | 50.0 | 144.8 | 54.000004 | 3.729000 | 0.069056 |
| 57 | 50.0 | 144.8 | 81.000000 | 5.593500 | 0.069056 |
| 57 | 50.0 | 144.8 | 108.000008 | 7.458000 | 0.069056 |
| 57 | 50.0 | 144.8 | 135.000000 | 9.661500 | 0.071567 |
| 57 | 50.0 | 144.8 | 162.000000 | 11.695499 | 0.072194 |
| 57 | 50.0 | 144.8 | 188.999985 | 14.238000 | 0.075333 |
| 57 | 50.0 | 144.8 | 216.000015 | 16.611000 | 0.076903 |
| 57 | 50.0 | 144.8 | 242.999985 | 19.492500 | 0.080216 |
| 57 | 50.0 | 144.8 | 270.000000 | 22.204500 | 0.082239 |

ANTHRACENE OIL - COOLING

| | | | | | |
|---|---|---|---|---|---|
| 15 | 0.0 | 101.0 | 93.599998 | 0.724500 | 0.007740 |
| 15 | 0.0 | 101.0 | 187.199997 | 1.231650 | 0.006579 |
| 15 | 0.0 | 101.0 | 280.799988 | 1.811250 | 0.006450 |
| 15 | 0.0 | 101.0 | 374.399994 | 2.535750 | 0.006773 |
| 15 | 0.0 | 101.0 | 468.000000 | 3.042900 | 0.006502 |
| 15 | 0.0 | 101.0 | 561.599976 | 3.694950 | 0.006579 |
| 15 | 0.0 | 101.0 | 655.199951 | 4.347000 | 0.006635 |
| 15 | 0.0 | 101.0 | 748.799988 | 5.071500 | 0.006773 |
| 15 | 0.0 | 101.0 | 842.399963 | 5.723550 | 0.006794 |
| 15 | 0.0 | 101.0 | 936.000000 | 6.375600 | 0.006812 |
| 16 | 0.0 | 42.0 | 58.499996 | 8.114400 | 0.138708 |
| 16 | 0.0 | 42.0 | 116.999992 | 15.890701 | 0.135818 |
| 16 | 0.0 | 42.0 | 146.250000 | 19.609800 | 0.134084 |
| 16 | 0.0 | 42.0 | 175.500000 | 23.328901 | 0.132928 |
| 16 | 0.0 | 42.0 | 233.999985 | 31.105202 | 0.132928 |
| 16 | 0.0 | 42.0 | 292.500000 | 38.543400 | 0.131772 |
| 16 | 0.0 | 42.0 | 321.750000 | 42.600601 | 0.132403 |
| 16 | 0.0 | 42.0 | 351.000000 | 46.319702 | 0.131965 |
| 16 | 0.0 | 42.0 | 409.499969 | 53.757900 | 0.131277 |
| 16 | 0.0 | 42.0 | 467.999969 | 61.534203 | 0.131483 |
| 127 | 0.0 | 125.6 | 13.500001 | 0.226000 | 0.016741 |
| 127 | 0.0 | 125.6 | 27.000002 | 0.282500 | 0.010463 |
| 127 | 0.0 | 125.6 | 40.500000 | 0.339000 | 0.008370 |
| 127 | 0.0 | 125.6 | 54.000004 | 0.372900 | 0.006906 |
| 127 | 0.0 | 125.6 | 67.500000 | 0.452000 | 0.006696 |
| 127 | 0.0 | 125.6 | 81.000000 | 0.565000 | 0.006975 |
| 127 | 0.0 | 125.6 | 94.499992 | 0.678000 | 0.007175 |
| 127 | 0.0 | 125.6 | 108.000008 | 0.791000 | 0.007324 |
| 127 | 0.0 | 125.6 | 121.499992 | 0.904000 | 0.007440 |
| 127 | 0.0 | 125.6 | 135.000000 | 1.017000 | 0.007533 |
| 128 | 0.0 | 107.0 | 13.500001 | 0.169500 | 0.012556 |
| 128 | 0.0 | 107.0 | 27.000002 | 0.203400 | 0.007533 |
| 128 | 0.0 | 107.0 | 40.500000 | 0.271200 | 0.006696 |
| 128 | 0.0 | 107.0 | 54.000004 | 0.339000 | 0.006278 |
| 128 | 0.0 | 107.0 | 67.500000 | 0.423750 | 0.006278 |
| 128 | 0.0 | 107.0 | 81.000000 | 0.508500 | 0.006278 |
| 128 | 0.0 | 107.0 | 94.499992 | 0.644100 | 0.006816 |
| 128 | 0.0 | 107.0 | 108.000008 | 0.762750 | 0.007062 |
| 128 | 0.0 | 107.0 | 121.499992 | 0.932250 | 0.007673 |
| 128 | 0.0 | 107.0 | 135.000000 | 1.101750 | 0.008161 |
| 129 | 0.0 | 88.1 | 18.000000 | 0.254250 | 0.014125 |
| 129 | 0.0 | 88.1 | 36.000000 | 0.339000 | 0.009417 |
| 129 | 0.0 | 88.1 | 54.000000 | 0.457650 | 0.008475 |
| 129 | 0.0 | 88.1 | 72.000000 | 0.593250 | 0.008240 |
| 129 | 0.0 | 88.1 | 90.000000 | 0.711900 | 0.007910 |
| 129 | 0.0 | 88.1 | 108.000000 | 0.881400 | 0.008161 |
| 129 | 0.0 | 88.1 | 125.999992 | 1.033950 | 0.008206 |
| 129 | 0.0 | 88.1 | 144.000000 | 1.356000 | 0.009417 |
| 129 | 0.0 | 88.1 | 161.999985 | 1.610250 | 0.009940 |
| 129 | 0.0 | 88.1 | 180.000000 | 1.949250 | 0.010829 |
| 130 | 0.0 | 69.9 | 18.000000 | 0.339000 | 0.018833 |
| 130 | 0.0 | 69.9 | 36.000000 | 0.508500 | 0.014125 |
| 130 | 0.0 | 69.9 | 54.000000 | 0.762750 | 0.014125 |
| 130 | 0.0 | 69.9 | 72.000000 | 0.983100 | 0.013654 |
| 130 | 0.0 | 69.9 | 90.000000 | 1.186500 | 0.013183 |
| 130 | 0.0 | 69.9 | 108.000000 | 1.440750 | 0.013340 |
| 130 | 0.0 | 69.9 | 125.999992 | 1.661100 | 0.013183 |
| 130 | 0.0 | 69.9 | 144.000000 | 1.915350 | 0.013301 |
| 130 | 0.0 | 69.9 | 161.999985 | 2.169600 | 0.013393 |
| 130 | 0.0 | 69.9 | 180.000000 | 2.457750 | 0.013654 |
| 131 | 0.0 | 49.8 | 18.000000 | 0.932250 | 0.051792 |

| | | | | | |
|---|---|---|---|---|---|
| 131 | 0.0 | 49.8 | 36.000000 | 1.864500 | 0.051792 |
| 131 | 0.0 | 49.8 | 54.000000 | 2.486000 | 0.046037 |
| 131 | 0.0 | 49.8 | 72.000000 | 3.107500 | 0.043160 |
| 131 | 0.0 | 49.8 | 90.000000 | 3.977600 | 0.044196 |
| 131 | 0.0 | 49.8 | 108.000000 | 4.785550 | 0.044311 |
| 131 | 0.0 | 49.8 | 125.999992 | 5.593500 | 0.044393 |
| 131 | 0.0 | 49.8 | 144.000000 | 6.277150 | 0.043591 |
| 131 | 0.0 | 49.8 | 161.999985 | 7.147250 | 0.044119 |
| 131 | 0.0 | 49.8 | 180.000000 | 8.079500 | 0.044886 |

10% w/w COAL-ANTHRACENE OIL - COOLING

| | | | | | |
|---|---|---|---|---|---|
| 28 | 10.0 | 40.4 | 22.500000 | 5.763000 | 0.256133 |
| 28 | 10.0 | 40.4 | 45.000000 | 10.848000 | 0.241067 |
| 28 | 10.0 | 40.4 | 67.500000 | 16.271999 | 0.241067 |
| 28 | 10.0 | 40.4 | 90.000000 | 21.695999 | 0.241067 |
| 28 | 10.0 | 40.4 | 112.500000 | 27.119999 | 0.241067 |
| 28 | 10.0 | 40.4 | 135.000000 | 32.543999 | 0.241067 |
| 28 | 10.0 | 40.4 | 157.500000 | 37.629002 | 0.238914 |
| 28 | 10.0 | 40.4 | 180.000000 | 43.052998 | 0.239183 |
| 28 | 10.0 | 40.4 | 202.499985 | 48.138000 | 0.237719 |
| 28 | 10.0 | 40.4 | 225.000000 | 52.883999 | 0.235040 |
| 132 | 10.0 | 126.0 | 67.500000 | 0.423750 | 0.006278 |
| 132 | 10.0 | 126.0 | 90.000000 | 0.593250 | 0.006592 |
| 132 | 10.0 | 126.0 | 112.500000 | 0.762750 | 0.006780 |
| 132 | 10.0 | 126.0 | 123.750008 | 0.847500 | 0.006848 |
| 132 | 10.0 | 126.0 | 135.000000 | 0.932250 | 0.006906 |
| 132 | 10.0 | 126.0 | 146.250000 | 1.050900 | 0.007186 |
| 132 | 10.0 | 126.0 | 157.500000 | 1.186500 | 0.007533 |
| 132 | 10.0 | 126.0 | 180.000000 | 1.356000 | 0.007533 |
| 132 | 10.0 | 126.0 | 202.499985 | 1.525500 | 0.007533 |
| 132 | 10.0 | 126.0 | 225.000000 | 1.779750 | 0.007910 |
| 133 | 10.0 | 106.8 | 36.000000 | 0.339000 | 0.009417 |
| 133 | 10.0 | 106.8 | 54.000000 | 0.423750 | 0.007847 |
| 133 | 10.0 | 106.8 | 72.000000 | 0.508500 | 0.007062 |
| 133 | 10.0 | 106.8 | 90.000000 | 0.644100 | 0.007157 |
| 133 | 10.0 | 106.8 | 108.000000 | 0.847500 | 0.007847 |
| 133 | 10.0 | 106.8 | 125.999992 | 1.017000 | 0.008071 |
| 133 | 10.0 | 106.8 | 135.000000 | 1.101750 | 0.008161 |
| 133 | 10.0 | 106.8 | 144.000000 | 1.220400 | 0.008475 |
| 133 | 10.0 | 106.8 | 161.999985 | 1.491600 | 0.009207 |
| 133 | 10.0 | 106.8 | 180.000000 | 1.695000 | 0.009417 |
| 134 | 10.0 | 87.5 | 36.000000 | 0.423750 | 0.011771 |
| 134 | 10.0 | 87.5 | 54.000000 | 0.508500 | 0.009417 |
| 134 | 10.0 | 87.5 | 72.000000 | 0.627150 | 0.008710 |
| 134 | 10.0 | 87.5 | 90.000000 | 0.762750 | 0.008475 |
| 134 | 10.0 | 87.5 | 108.000000 | 0.898350 | 0.008318 |
| 134 | 10.0 | 87.5 | 125.999992 | 1.067850 | 0.008475 |
| 134 | 10.0 | 87.5 | 135.000000 | 1.152600 | 0.008538 |
| 134 | 10.0 | 87.5 | 144.000000 | 1.237350 | 0.008593 |
| 134 | 10.0 | 87.5 | 161.999985 | 1.525500 | 0.009417 |
| 134 | 10.0 | 87.5 | 180.000000 | 1.898400 | 0.010547 |
| 135 | 10.0 | 67.5 | 18.000000 | 0.339000 | 0.018833 |
| 135 | 10.0 | 67.5 | 36.000000 | 0.621500 | 0.017264 |
| 135 | 10.0 | 67.5 | 54.000000 | 0.847500 | 0.015694 |
| 135 | 10.0 | 67.5 | 72.000000 | 1.130000 | 0.015694 |
| 135 | 10.0 | 67.5 | 90.000000 | 1.412500 | 0.015694 |
| 135 | 10.0 | 67.5 | 108.000000 | 1.695000 | 0.015694 |
| 135 | 10.0 | 67.5 | 125.999992 | 1.977500 | 0.015694 |
| 135 | 10.0 | 67.5 | 144.000000 | 2.260000 | 0.015694 |
| 135 | 10.0 | 67.5 | 161.999985 | 2.542500 | 0.015694 |
| 135 | 10.0 | 67.5 | 180.000000 | 2.825000 | 0.015694 |
| 136 | 10.0 | 49.0 | 18.000000 | 1.130000 | 0.062778 |
| 136 | 10.0 | 49.0 | 36.000000 | 1.977500 | 0.054931 |
| 136 | 10.0 | 49.0 | 54.000000 | 2.966250 | 0.054931 |
| 136 | 10.0 | 49.0 | 72.000000 | 3.729000 | 0.051792 |
| 136 | 10.0 | 49.0 | 90.000000 | 4.661250 | 0.051792 |
| 136 | 10.0 | 49.0 | 108.000000 | 5.508750 | 0.051007 |
| 136 | 10.0 | 49.0 | 125.999992 | 6.497500 | 0.051567 |
| 136 | 10.0 | 49.0 | 144.000000 | 7.345000 | 0.051007 |
| 136 | 10.0 | 49.0 | 161.999985 | 8.249000 | 0.050920 |
| 136 | 10.0 | 49.0 | 180.000000 | 9.181250 | 0.051007 |

30% w/w COAL-ANTHRACENE OIL - COOLING

| | | | | | |
|---|---|---|---|---|---|
| 41 | 30.0 | 122.2 | 31.500002 | 0.565000 | 0.017937 |
| 41 | 30.0 | 122.2 | 63.000004 | 0.904000 | 0.014349 |
| 41 | 30.0 | 122.2 | 94.500000 | 1.243000 | 0.013153 |
| 41 | 30.0 | 122.2 | 126.000008 | 1.582000 | 0.012556 |
| 41 | 30.0 | 122.2 | 141.749985 | 1.751500 | 0.012356 |
| 41 | 30.0 | 122.2 | 157.500000 | 1.921000 | 0.012197 |
| 41 | 30.0 | 122.2 | 173.250015 | 2.147000 | 0.012392 |
| 41 | 30.0 | 122.2 | 189.000000 | 2.373000 | 0.012556 |
| 41 | 30.0 | 122.2 | 204.750000 | 2.599000 | 0.012694 |
| 41 | 30.0 | 122.2 | 220.499985 | 2.938000 | 0.013324 |
| 42 | 30.0 | 97.8 | 31.500002 | 0.762750 | 0.024214 |
| 42 | 30.0 | 97.8 | 63.000004 | 1.356000 | 0.021524 |
| 42 | 30.0 | 97.8 | 94.500000 | 1.949250 | 0.020627 |
| 42 | 30.0 | 97.8 | 126.000008 | 2.542500 | 0.020179 |
| 42 | 30.0 | 97.8 | 157.500000 | 3.220500 | 0.020448 |
| 42 | 30.0 | 97.8 | 189.000000 | 3.898500 | 0.020627 |
| 42 | 30.0 | 97.8 | 220.499985 | 4.576500 | 0.020755 |
| 42 | 30.0 | 97.8 | 252.000015 | 5.339250 | 0.021187 |
| 42 | 30.0 | 97.8 | 283.499969 | 6.102000 | 0.021524 |
| 42 | 30.0 | 97.8 | 315.000000 | 6.949500 | 0.022062 |
| 43 | 30.0 | 68.5 | 31.500002 | 2.034000 | 0.064571 |
| 43 | 30.0 | 68.5 | 63.000004 | 3.559500 | 0.056500 |
| 43 | 30.0 | 68.5 | 94.500000 | 5.424000 | 0.057397 |
| 43 | 30.0 | 68.5 | 126.000008 | 7.119000 | 0.056500 |
| 43 | 30.0 | 68.5 | 157.500000 | 8.814000 | 0.055962 |
| 43 | 30.0 | 68.5 | 189.000000 | 10.509001 | 0.055603 |
| 43 | 30.0 | 68.5 | 220.499985 | 12.373501 | 0.056116 |
| 43 | 30.0 | 68.5 | 252.000015 | 14.068501 | 0.055827 |
| 43 | 30.0 | 68.5 | 283.499969 | 15.933000 | 0.056201 |
| 43 | 30.0 | 68.5 | 315.000000 | 17.797499 | 0.056500 |
| 44 | 30.0 | 49.5 | 31.500002 | 7.514500 | 0.238556 |
| 44 | 30.0 | 49.5 | 63.000004 | 14.633500 | 0.232278 |
| 44 | 30.0 | 49.5 | 94.500000 | 21.357002 | 0.226000 |
| 44 | 30.0 | 49.5 | 126.000008 | 28.080500 | 0.222861 |
| 44 | 30.0 | 49.5 | 157.500000 | 35.199501 | 0.223489 |
| 44 | 30.0 | 49.5 | 189.000000 | 42.714005 | 0.226000 |
| 44 | 30.0 | 49.5 | 220.499985 | 49.833000 | 0.226000 |
| 44 | 30.0 | 49.5 | 252.000015 | 56.952000 | 0.226000 |
| 44 | 30.0 | 49.5 | 283.499969 | 64.466499 | 0.227395 |
| 44 | 30.0 | 49.5 | 315.000000 | 71.189995 | 0.226000 |
| 45 | 30.0 | 30.2 | 13.500001 | 10.735000 | 0.795185 |
| 45 | 30.0 | 30.2 | 27.000002 | 19.775000 | 0.732407 |
| 45 | 30.0 | 30.2 | 40.500000 | 28.814999 | 0.711481 |
| 45 | 30.0 | 30.2 | 54.000004 | 37.290001 | 0.690556 |
| 45 | 30.0 | 30.2 | 67.500000 | 46.329998 | 0.686370 |
| 45 | 30.0 | 30.2 | 81.000000 | 54.805000 | 0.676605 |
| 45 | 30.0 | 30.2 | 94.499992 | 63.279999 | 0.669630 |
| 45 | 30.0 | 30.2 | 108.000008 | 71.754997 | 0.664398 |
| 45 | 30.0 | 30.2 | 121.499992 | 80.229996 | 0.660329 |
| 45 | 30.0 | 30.2 | 135.000000 | 87.574997 | 0.648704 |

50% w/w COAL-ANTHRACENE OIL - COOLING

| | | | | | |
|---|---|---|---|---|---|
| 58 | 50.0 | 116.3 | 22.500000 | 4.068000 | 0.180800 |
| 58 | 50.0 | 116.3 | 45.000000 | 7.684000 | 0.170756 |
| 58 | 50.0 | 116.3 | 67.500000 | 11.300000 | 0.167407 |
| 58 | 50.0 | 116.3 | 90.000000 | 14.690000 | 0.163222 |
| 58 | 50.0 | 116.3 | 112.500000 | 18.080000 | 0.160711 |
| 58 | 50.0 | 116.3 | 135.000000 | 21.696001 | 0.160711 |
| 58 | 50.0 | 116.3 | 157.500000 | 25.086000 | 0.159276 |
| 58 | 50.0 | 116.3 | 180.000000 | 28.476000 | 0.158200 |
| 58 | 50.0 | 116.3 | 202.499985 | 31.865999 | 0.157363 |
| 58 | 50.0 | 116.3 | 225.000000 | 34.803997 | 0.154684 |
| 59 | 50.0 | 89.8 | 22.500000 | 8.644500 | 0.384200 |
| 59 | 50.0 | 89.8 | 45.000000 | 16.780500 | 0.372900 |
| 59 | 50.0 | 89.8 | 67.500000 | 24.408001 | 0.361600 |
| 59 | 50.0 | 89.8 | 90.000000 | 32.035500 | 0.355950 |
| 59 | 50.0 | 89.8 | 112.500000 | 38.646000 | 0.343520 |
| 59 | 50.0 | 89.8 | 135.000000 | 44.747997 | 0.331467 |
| 59 | 50.0 | 89.8 | 157.500000 | 51.866997 | 0.329314 |
| 59 | 50.0 | 89.8 | 180.000000 | 58.477501 | 0.324875 |
| 59 | 50.0 | 89.8 | 202.499985 | 65.596497 | 0.323933 |
| 59 | 50.0 | 89.8 | 225.000000 | 72.715500 | 0.323180 |
| 60 | 50.0 | 69.5 | 9.000000 | 13.560000 | 1.506667 |
| 60 | 50.0 | 69.5 | 18.000000 | 25.424999 | 1.412500 |
| 60 | 50.0 | 69.5 | 27.000000 | 36.724998 | 1.360185 |
| 60 | 50.0 | 69.5 | 36.000000 | 46.329998 | 1.286944 |
| 60 | 50.0 | 69.5 | 45.000000 | 55.935001 | 1.243000 |
| 60 | 50.0 | 69.5 | 54.000000 | 64.974998 | 1.203241 |
| 60 | 50.0 | 69.5 | 62.999996 | 73.449997 | 1.165873 |
| 60 | 50.0 | 69.5 | 72.000000 | 81.360001 | 1.130000 |
| 60 | 50.0 | 69.5 | 80.999992 | 88.705002 | 1.095124 |
| 60 | 50.0 | 69.5 | 90.000000 | 96.050003 | 1.067222 |
| 61 | 50.0 | 53.5 | 2.250000 | 10.170000 | 4.520000 |
| 61 | 50.0 | 53.5 | 4.500000 | 19.775000 | 4.394444 |
| 61 | 50.0 | 53.5 | 9.000000 | 37.290001 | 4.143333 |
| 61 | 50.0 | 53.5 | 11.250000 | 45.200001 | 4.017778 |
| 61 | 50.0 | 53.5 | 13.500000 | 52.544998 | 3.892222 |
| 61 | 50.0 | 53.5 | 18.000000 | 66.669998 | 3.703889 |
| 61 | 50.0 | 53.5 | 22.500000 | 79.665001 | 3.540667 |
| 61 | 50.0 | 53.5 | 27.000000 | 91.529999 | 3.390000 |
| 61 | 50.0 | 53.5 | 31.499998 | 102.830002 | 3.264445 |
| 61 | 50.0 | 53.5 | 35.549999 | 113.000000 | 3.178622 |

# BITUMEN HEATING

| | | | | | |
|---|---|---|---|---|---|
| 62 | 0.0 | 25.3 | 0.360000 | 9.605000 | 26.680555 |
| 62 | 0.0 | 25.3 | 0.720000 | 19.775000 | 27.465277 |
| 62 | 0.0 | 25.3 | 1.080000 | 29.944998 | 27.726849 |
| 62 | 0.0 | 25.3 | 1.440000 | 40.114998 | 27.857635 |
| 62 | 0.0 | 25.3 | 1.800000 | 49.719997 | 27.622219 |
| 62 | 0.0 | 25.3 | 2.160000 | 59.889996 | 27.726849 |
| 62 | 0.0 | 25.3 | 2.520000 | 70.060005 | 27.801590 |
| 62 | 0.0 | 25.3 | 2.880000 | 79.665001 | 27.661457 |
| 62 | 0.0 | 25.3 | 3.240000 | 89.834999 | 27.726854 |
| 62 | 0.0 | 25.3 | 3.600000 | 99.439995 | 27.622219 |
| 63 | 0.0 | 34.5 | 1.125000 | 10.170000 | 9.040000 |
| 63 | 0.0 | 34.5 | 2.250000 | 20.340000 | 9.040000 |
| 63 | 0.0 | 34.5 | 3.375000 | 30.510002 | 9.040001 |
| 63 | 0.0 | 34.5 | 4.500000 | 41.810001 | 9.291111 |
| 63 | 0.0 | 34.5 | 5.625000 | 51.415001 | 9.140445 |
| 63 | 0.0 | 34.5 | 6.750000 | 62.150002 | 9.207408 |
| 63 | 0.0 | 34.5 | 7.875000 | 72.320000 | 9.183493 |
| 63 | 0.0 | 34.5 | 9.000000 | 83.055000 | 9.228333 |
| 63 | 0.0 | 34.5 | 10.124999 | 93.224998 | 9.207408 |
| 63 | 0.0 | 34.5 | 11.250000 | 102.830002 | 9.140445 |
| 64 | 0.0 | 40.8 | 3.150000 | 10.170000 | 3.228571 |
| 64 | 0.0 | 40.8 | 6.300000 | 20.905001 | 3.318254 |
| 64 | 0.0 | 40.8 | 9.450000 | 31.639999 | 3.348148 |
| 64 | 0.0 | 40.8 | 12.600000 | 42.375000 | 3.363095 |
| 64 | 0.0 | 40.8 | 15.750000 | 53.109997 | 3.372063 |
| 64 | 0.0 | 40.8 | 18.900000 | 63.844997 | 3.378042 |
| 64 | 0.0 | 40.8 | 22.049999 | 74.580002 | 3.382313 |
| 64 | 0.0 | 40.8 | 25.200001 | 85.315002 | 3.385516 |
| 64 | 0.0 | 40.8 | 28.349998 | 95.485001 | 3.368078 |
| 64 | 0.0 | 40.8 | 31.500000 | 105.655006 | 3.354127 |
| 65 | 0.0 | 49.0 | 6.750000 | 10.170000 | 1.506667 |
| 65 | 0.0 | 49.0 | 13.500001 | 19.775000 | 1.464815 |
| 65 | 0.0 | 49.0 | 20.250000 | 29.379999 | 1.450864 |
| 65 | 0.0 | 49.0 | 27.000002 | 38.985001 | 1.443889 |
| 65 | 0.0 | 49.0 | 33.750000 | 49.154999 | 1.456444 |
| 65 | 0.0 | 49.0 | 40.500000 | 58.759998 | 1.450864 |
| 65 | 0.0 | 49.0 | 47.249996 | 68.365005 | 1.446879 |
| 65 | 0.0 | 49.0 | 54.000004 | 77.970001 | 1.443889 |
| 65 | 0.0 | 49.0 | 60.749996 | 87.574997 | 1.441564 |
| 65 | 0.0 | 49.0 | 67.500000 | 97.180000 | 1.439704 |
| 66 | 0.0 | 61.2 | 13.500001 | 9.040000 | 0.669630 |
| 66 | 0.0 | 61.2 | 27.000002 | 18.080000 | 0.669630 |
| 66 | 0.0 | 61.2 | 40.500000 | 27.120001 | 0.669630 |
| 66 | 0.0 | 61.2 | 54.000004 | 36.724998 | 0.680093 |
| 66 | 0.0 | 61.2 | 67.500000 | 45.764999 | 0.678000 |
| 66 | 0.0 | 61.2 | 81.000000 | 54.805000 | 0.676605 |
| 66 | 0.0 | 61.2 | 94.499992 | 64.410004 | 0.681587 |
| 66 | 0.0 | 61.2 | 108.000008 | 74.014999 | 0.685324 |
| 66 | 0.0 | 61.2 | 121.499992 | 83.055000 | 0.683580 |
| 66 | 0.0 | 61.2 | 135.000000 | 92.659996 | 0.686370 |
| 67 | 0.0 | 71.2 | 24.750002 | 9.040000 | 0.365252 |
| 67 | 0.0 | 71.2 | 49.500004 | 18.080000 | 0.365252 |
| 67 | 0.0 | 71.2 | 74.250000 | 27.120001 | 0.365253 |
| 67 | 0.0 | 71.2 | 99.000008 | 36.160000 | 0.365252 |
| 67 | 0.0 | 71.2 | 123.750000 | 45.200001 | 0.365253 |
| 67 | 0.0 | 71.2 | 148.500000 | 54.805000 | 0.369057 |
| 67 | 0.0 | 71.2 | 173.249985 | 63.844997 | 0.368514 |
| 67 | 0.0 | 71.2 | 198.000015 | 72.884995 | 0.368106 |
| 67 | 0.0 | 71.2 | 222.749985 | 81.925003 | 0.367789 |
| 67 | 0.0 | 71.2 | 247.500000 | 90.400002 | 0.365253 |
| 68 | 0.0 | 82.0 | 31.500002 | 7.119000 | 0.226000 |

| | | | | | |
|---|---|---|---|---|---|
| 68 | 0.0 | 82.0 | 63.000004 | 13.842500 | 0.219722 |
| 68 | 0.0 | 82.0 | 94.500000 | 20.961498 | 0.221815 |
| 68 | 0.0 | 82.0 | 126.000008 | 28.080500 | 0.222861 |
| 68 | 0.0 | 82.0 | 157.500000 | 35.199501 | 0.223489 |
| 68 | 0.0 | 82.0 | 189.000000 | 42.318501 | 0.223907 |
| 68 | 0.0 | 82.0 | 220.499985 | 49.437500 | 0.224206 |
| 68 | 0.0 | 82.0 | 252.000015 | 56.556496 | 0.224431 |
| 68 | 0.0 | 82.0 | 283.499969 | 63.675503 | 0.224605 |
| 68 | 0.0 | 82.0 | 315.000000 | 70.399002 | 0.223489 |
| 69 | 0.0 | 93.2 | 31.500002 | 4.520000 | 0.143492 |
| 69 | 0.0 | 93.2 | 63.000004 | 8.757501 | 0.139008 |
| 69 | 0.0 | 93.2 | 94.500000 | 12.995000 | 0.137513 |
| 69 | 0.0 | 93.2 | 126.000008 | 17.232500 | 0.136766 |
| 69 | 0.0 | 93.2 | 157.500000 | 21.752499 | 0.138111 |
| 69 | 0.0 | 93.2 | 189.000000 | 25.990000 | 0.137513 |
| 69 | 0.0 | 93.2 | 220.499985 | 30.510002 | 0.138367 |
| 69 | 0.0 | 93.2 | 252.000015 | 35.030003 | 0.139008 |
| 69 | 0.0 | 93.2 | 283.499969 | 39.267498 | 0.138510 |
| 69 | 0.0 | 93.2 | 315.000000 | 43.787498 | 0.139008 |
| 70 | 0.0 | 109.8 | 31.500002 | 2.542500 | 0.080714 |
| 70 | 0.0 | 109.8 | 63.000004 | 4.576500 | 0.072643 |
| 70 | 0.0 | 109.8 | 94.500000 | 6.441000 | 0.068159 |
| 70 | 0.0 | 109.8 | 126.000008 | 8.475000 | 0.067262 |
| 70 | 0.0 | 109.8 | 157.500000 | 10.509001 | 0.066724 |
| 70 | 0.0 | 109.8 | 189.000000 | 12.543000 | 0.066365 |
| 70 | 0.0 | 109.8 | 220.499985 | 14.746500 | 0.066878 |
| 70 | 0.0 | 109.8 | 252.000015 | 16.780500 | 0.066589 |
| 70 | 0.0 | 109.8 | 283.499969 | 18.983999 | 0.066963 |
| 70 | 0.0 | 109.8 | 315.000000 | 21.018002 | 0.066724 |
| 71 | 0.0 | 123.0 | 31.500002 | 1.582000 | 0.050222 |
| 71 | 0.0 | 123.0 | 63.000004 | 3.051000 | 0.048429 |
| 71 | 0.0 | 123.0 | 94.500000 | 4.520000 | 0.047831 |
| 71 | 0.0 | 123.0 | 126.000008 | 5.989000 | 0.047532 |
| 71 | 0.0 | 123.0 | 157.500000 | 7.571000 | 0.048070 |
| 71 | 0.0 | 123.0 | 189.000000 | 9.153000 | 0.048429 |
| 71 | 0.0 | 123.0 | 220.499985 | 10.735001 | 0.048685 |
| 71 | 0.0 | 123.0 | 252.000015 | 12.317000 | 0.048877 |
| 71 | 0.0 | 123.0 | 283.499969 | 14.012001 | 0.049425 |
| 71 | 0.0 | 123.0 | 315.000000 | 15.707000 | 0.049863 |
| 72 | 0.0 | 131.8 | 27.000002 | 1.130000 | 0.041852 |
| 72 | 0.0 | 131.8 | 54.000004 | 2.147000 | 0.039759 |
| 72 | 0.0 | 131.8 | 81.000000 | 3.164000 | 0.039062 |
| 72 | 0.0 | 131.8 | 108.000008 | 4.181000 | 0.038713 |
| 72 | 0.0 | 131.8 | 135.000000 | 5.198000 | 0.038504 |
| 72 | 0.0 | 131.8 | 162.000000 | 6.215000 | 0.038364 |
| 72 | 0.0 | 131.8 | 188.999985 | 7.232000 | 0.038265 |
| 72 | 0.0 | 131.8 | 216.000015 | 8.249001 | 0.038190 |
| 72 | 0.0 | 131.8 | 242.999985 | 9.379000 | 0.038597 |
| 72 | 0.0 | 131.8 | 270.000000 | 10.509000 | 0.038922 |
| 73 | 0.0 | 142.0 | 27.000002 | 0.762750 | 0.028250 |
| 73 | 0.0 | 142.0 | 54.000004 | 1.610250 | 0.029819 |
| 73 | 0.0 | 142.0 | 81.000000 | 2.373000 | 0.029296 |
| 73 | 0.0 | 142.0 | 108.000008 | 3.135750 | 0.029035 |
| 73 | 0.0 | 142.0 | 135.000000 | 3.983250 | 0.029506 |
| 73 | 0.0 | 142.0 | 162.000000 | 4.830750 | 0.029819 |
| 73 | 0.0 | 142.0 | 188.999985 | 5.678250 | 0.030044 |
| 73 | 0.0 | 142.0 | 216.000015 | 6.525750 | 0.030212 |
| 73 | 0.0 | 142.0 | 242.999985 | 7.458000 | 0.030691 |
| 73 | 0.0 | 142.0 | 270.000000 | 8.390250 | 0.031075 |
| 74 | 0.0 | 151.0 | 27.000002 | 0.678000 | 0.025111 |
| 74 | [illegible] | 151.0 | 54.000004 | 1.356000 | 0.025111 |

| | | | | | |
|---|---|---|---|---|---|
| 74 | 0.0 | 151.0 | 81.000000 | 1.949250 | 0.024065 |
| 74 | 0.0 | 151.0 | 108.000008 | 2.627250 | 0.024326 |
| 74 | 0.0 | 151.0 | 135.000000 | 3.305250 | 0.024483 |
| 74 | 0.0 | 151.0 | 162.000000 | 3.983250 | 0.024588 |
| 74 | 0.0 | 151.0 | 188.999985 | 4.661250 | 0.024663 |
| 74 | 0.0 | 151.0 | 216.000015 | 5.339250 | 0.024719 |
| 74 | 0.0 | 151.0 | 242.999985 | 6.102000 | 0.025111 |
| 74 | 0.0 | 151.0 | 270.000000 | 6.864750 | 0.025425 |

10% w/w COAL-BITUMEN - HEATING

| | | | | | |
|---|---|---|---|---|---|
| 80 | 10.0 | 24.8 | 0.225000 | 10.170000 | 45.199997 |
| 80 | 10.0 | 24.8 | 0.450000 | 20.340000 | 45.199997 |
| 80 | 10.0 | 24.8 | 0.675000 | 30.510002 | 45.200001 |
| 80 | 10.0 | 24.8 | 0.900000 | 39.549999 | 43.944443 |
| 80 | 10.0 | 24.8 | 1.125000 | 49.154999 | 43.693333 |
| 80 | 10.0 | 24.8 | 1.350000 | 58.759998 | 43.525925 |
| 80 | 10.0 | 24.8 | 1.575000 | 68.930000 | 43.765083 |
| 80 | 10.0 | 24.8 | 1.800000 | 77.404999 | 43.002777 |
| 80 | 10.0 | 24.8 | 2.025000 | 86.445000 | 42.688892 |
| 80 | 10.0 | 24.8 | 2.250000 | 95.485001 | 42.437778 |
| 81 | 10.0 | 34.0 | 0.675000 | 10.170000 | 15.066667 |
| 81 | 10.0 | 34.0 | 1.350000 | 20.340000 | 15.066667 |
| 81 | 10.0 | 34.0 | 2.025000 | 29.944998 | 14.787653 |
| 81 | 10.0 | 34.0 | 2.700000 | 38.985001 | 14.438889 |
| 81 | 10.0 | 34.0 | 3.375000 | 49.154999 | 14.564445 |
| 81 | 10.0 | 34.0 | 4.050000 | 58.195000 | 14.369135 |
| 81 | 10.0 | 34.0 | 4.725000 | 67.235008 | 14.229631 |
| 81 | 10.0 | 34.0 | 5.400000 | 76.840004 | 14.229630 |
| 81 | 10.0 | 34.0 | 6.075000 | 85.879997 | 14.136625 |
| 81 | 10.0 | 34.0 | 6.750000 | 94.919998 | 14.062222 |
| 82 | 10.0 | 44.0 | 2.025000 | 11.300000 | 5.580247 |
| 82 | 10.0 | 44.0 | 4.050000 | 21.469999 | 5.301234 |
| 82 | 10.0 | 44.0 | 6.075000 | 31.639999 | 5.208230 |
| 82 | 10.0 | 44.0 | 8.100000 | 42.375000 | 5.231481 |
| 82 | 10.0 | 44.0 | 10.125000 | 52.544998 | 5.189630 |
| 82 | 10.0 | 44.0 | 12.150001 | 62.715000 | 5.161728 |
| 82 | 10.0 | 44.0 | 14.174999 | 72.320000 | 5.101940 |
| 82 | 10.0 | 44.0 | 16.200001 | 82.490005 | 5.091975 |
| 82 | 10.0 | 44.0 | 18.224998 | 92.095001 | 5.053224 |
| 82 | 10.0 | 44.0 | 20.250000 | 101.699997 | 5.022222 |
| 83 | 10.0 | 52.9 | 4.050000 | 10.170000 | 2.511111 |
| 83 | 10.0 | 52.9 | 8.100000 | 19.775000 | 2.441358 |
| 83 | 10.0 | 52.9 | 12.150001 | 29.379999 | 2.418107 |
| 83 | 10.0 | 52.9 | 16.200001 | 38.985001 | 2.406482 |
| 83 | 10.0 | 52.9 | 20.250000 | 48.590000 | 2.399506 |
| 83 | 10.0 | 52.9 | 24.300001 | 58.195000 | 2.394856 |
| 83 | 10.0 | 52.9 | 28.349998 | 67.800003 | 2.391535 |
| 83 | 10.0 | 52.9 | 32.400002 | 76.840004 | 2.371605 |
| 83 | 10.0 | 52.9 | 36.449997 | 86.445000 | 2.371605 |
| 83 | 10.0 | 52.9 | 40.500000 | 94.919998 | 2.343704 |
| 84 | 10.0 | 63.0 | 9.000000 | 11.300000 | 1.255556 |
| 84 | 10.0 | 63.0 | 18.000000 | 22.035000 | 1.224167 |
| 84 | 10.0 | 63.0 | 27.000000 | 32.770000 | 1.213704 |
| 84 | 10.0 | 63.0 | 36.000000 | 43.504997 | 1.208472 |
| 84 | 10.0 | 63.0 | 45.000000 | 53.675003 | 1.192778 |
| 84 | 10.0 | 63.0 | 54.000000 | 63.844997 | 1.182315 |
| 84 | 10.0 | 63.0 | 62.999996 | 74.580002 | 1.183810 |
| 84 | 10.0 | 63.0 | 72.000000 | 84.750000 | 1.177083 |
| 84 | 10.0 | 63.0 | 80.999992 | 95.485001 | 1.178827 |
| 84 | 10.0 | 63.0 | 90.000000 | 105.089996 | 1.167667 |
| 85 | 10.0 | 73.8 | 16.200001 | 10.170000 | 0.627778 |
| 85 | 10.0 | 73.8 | 32.400002 | 19.775000 | 0.610339 |
| 85 | 10.0 | 73.8 | 48.600002 | 29.944998 | 0.616152 |
| 85 | 10.0 | 73.8 | 64.800003 | 40.114998 | 0.619059 |
| 85 | 10.0 | 73.8 | 81.000000 | 50.285000 | 0.620802 |
| 85 | 10.0 | 73.8 | 97.200005 | 60.455002 | 0.621965 |
| 85 | 10.0 | 73.8 | 113.399994 | 70.625000 | 0.622795 |
| 85 | 10.0 | 73.8 | 129.600006 | 80.794998 | 0.623418 |
| 85 | 10.0 | 73.8 | 145.799988 | 90.965004 | 0.623903 |
| 85 | 10.0 | 73.8 | 162.000000 | 100.570000 | 0.620802 |
| 86 | 10.0 | 83.2 | 20.250000 | 8.136000 | 0.401778 |

| | | | | | |
|---|---|---|---|---|---|
| 86 | 10.0 | 83.2 | 40.500000 | 15.820001 | 0.390617 |
| 86 | 10.0 | 83.2 | 60.750000 | 23.955999 | 0.394337 |
| 86 | 10.0 | 83.2 | 81.000000 | 32.091999 | 0.396198 |
| 86 | 10.0 | 83.2 | 101.250000 | 40.680000 | 0.401778 |
| 86 | 10.0 | 83.2 | 121.500000 | 48.816006 | 0.401778 |
| 86 | 10.0 | 83.2 | 141.750000 | 56.952000 | 0.401778 |
| 86 | 10.0 | 83.2 | 162.000000 | 65.540001 | 0.404568 |
| 86 | 10.0 | 83.2 | 182.249985 | 73.676003 | 0.404258 |
| 86 | 10.0 | 83.2 | 202.500000 | 81.812004 | 0.404010 |
| 87 | 10.0 | 91.4 | 22.500000 | 6.780000 | 0.301333 |
| 87 | 10.0 | 91.4 | 45.000000 | 12.656000 | 0.281244 |
| 87 | 10.0 | 91.4 | 67.500000 | 19.436001 | 0.287941 |
| 87 | 10.0 | 91.4 | 90.000000 | 25.764000 | 0.286267 |
| 87 | 10.0 | 91.4 | 112.500000 | 32.091999 | 0.285262 |
| 87 | 10.0 | 91.4 | 135.000000 | 38.872002 | 0.287941 |
| 87 | 10.0 | 91.4 | 157.500000 | 46.556000 | 0.295594 |
| 87 | 10.0 | 91.4 | 180.000000 | 51.980000 | 0.288778 |
| 87 | 10.0 | 91.4 | 202.499985 | 58.759998 | 0.290173 |
| 87 | 10.0 | 91.4 | 225.000000 | 65.540001 | 0.291289 |
| 88 | 10.0 | 101.2 | 22.500000 | 5.424000 | 0.241067 |
| 88 | 10.0 | 101.2 | 45.000000 | 10.509001 | 0.233533 |
| 88 | 10.0 | 101.2 | 67.500000 | 15.594000 | 0.231022 |
| 88 | 10.0 | 101.2 | 90.000000 | 20.679001 | 0.229767 |
| 88 | 10.0 | 101.2 | 112.500000 | 26.102999 | 0.232027 |
| 88 | 10.0 | 101.2 | 135.000000 | 31.527000 | 0.233533 |
| 88 | 10.0 | 101.2 | 157.500000 | 36.951000 | 0.234610 |
| 88 | 10.0 | 101.2 | 180.000000 | 42.375000 | 0.235417 |
| 88 | 10.0 | 101.2 | 202.499985 | 48.476997 | 0.239393 |
| 88 | 10.0 | 101.2 | 225.000000 | 53.223003 | 0.236547 |
| 89 | 10.0 | 114.2 | 22.500000 | 3.164000 | 0.140622 |
| 89 | 10.0 | 114.2 | 45.000000 | 5.876000 | 0.130578 |
| 89 | 10.0 | 114.2 | 67.500000 | 8.588000 | 0.127230 |
| 89 | 10.0 | 114.2 | 90.000000 | 11.300000 | 0.125556 |
| 89 | 10.0 | 114.2 | 112.500000 | 14.012001 | 0.124551 |
| 89 | 10.0 | 114.2 | 135.000000 | 16.950001 | 0.125556 |
| 89 | 10.0 | 114.2 | 157.500000 | 19.662001 | 0.124838 |
| 89 | 10.0 | 114.2 | 180.000000 | 22.600000 | 0.125556 |
| 89 | 10.0 | 114.2 | 202.499985 | 25.537998 | 0.126114 |
| 89 | 10.0 | 114.2 | 225.000000 | 28.476000 | 0.126560 |
| 90 | 10.0 | 128.4 | 22.500000 | 2.034000 | 0.090400 |
| 90 | 10.0 | 128.4 | 45.000000 | 3.616000 | 0.080356 |
| 90 | 10.0 | 128.4 | 67.500000 | 5.311000 | 0.078681 |
| 90 | 10.0 | 128.4 | 90.000000 | 6.893000 | 0.076589 |
| 90 | 10.0 | 128.4 | 112.500000 | 8.588000 | 0.076338 |
| 90 | 10.0 | 128.4 | 135.000000 | 10.283001 | 0.076170 |
| 90 | 10.0 | 128.4 | 157.500000 | 12.091001 | 0.076768 |
| 90 | 10.0 | 128.4 | 180.000000 | 13.786000 | 0.076589 |
| 90 | 10.0 | 128.4 | 202.499985 | 15.481000 | 0.076449 |
| 90 | 10.0 | 128.4 | 225.000000 | 17.289000 | 0.076840 |
| 91 | 10.0 | 144.6 | 22.500000 | 1.582000 | 0.070311 |
| 91 | 10.0 | 144.6 | 45.000000 | 2.712000 | 0.060267 |
| 91 | 10.0 | 144.6 | 67.500000 | 4.068000 | 0.060267 |
| 91 | 10.0 | 144.6 | 90.000000 | 5.424000 | 0.060267 |
| 91 | 10.0 | 144.6 | 112.500000 | 6.780000 | 0.060267 |
| 91 | 10.0 | 144.6 | 135.000000 | 8.136000 | 0.060267 |
| 91 | 10.0 | 144.6 | 157.500000 | 9.492000 | 0.060267 |
| 91 | 10.0 | 144.6 | 180.000000 | 10.848001 | 0.060267 |
| 91 | 10.0 | 144.6 | 202.499985 | 12.317000 | 0.060825 |
| 91 | 10.0 | 144.6 | 225.000000 | 13.673000 | 0.060769 |

30% w/w COAL-BITUMEN - HEATING

| | | | | | |
|---|---|---|---|---|---|
| 97 | 30.0 | 24.8 | 0.090000 | 10.735000 | 119.277771 |
| 97 | 30.0 | 24.8 | 0.180000 | 20.340000 | 113.000000 |
| 97 | 30.0 | 24.8 | 0.270000 | 31.075001 | 115.092590 |
| 97 | 30.0 | 24.8 | 0.360000 | 40.680000 | 113.000000 |
| 97 | 30.0 | 24.8 | 0.450000 | 50.285000 | 111.744438 |
| 97 | 30.0 | 24.8 | 0.540000 | 60.455002 | 111.953705 |
| 97 | 30.0 | 24.8 | 0.630000 | 72.320000 | 114.793648 |
| 97 | 30.0 | 24.8 | 0.720000 | 80.229996 | 111.430542 |
| 97 | 30.0 | 24.8 | 0.810000 | 91.529999 | 113.000008 |
| 97 | 30.0 | 24.8 | 0.900000 | 100.004997 | 111.116661 |
| 98 | 30.0 | 33.0 | 0.315000 | 11.865000 | 37.666668 |
| 98 | 30.0 | 33.0 | 0.630000 | 23.164999 | 36.769840 |
| 98 | 30.0 | 33.0 | 0.945000 | 35.595001 | 37.666668 |
| 98 | 30.0 | 33.0 | 1.260000 | 46.895000 | 37.218254 |
| 98 | 30.0 | 33.0 | 1.575000 | 58.759998 | 37.307938 |
| 98 | 30.0 | 33.0 | 1.890000 | 70.060005 | 37.068787 |
| 98 | 30.0 | 33.0 | 2.205000 | 81.360001 | 36.897961 |
| 98 | 30.0 | 33.0 | 2.520000 | 92.659996 | 36.769840 |
| 98 | 30.0 | 33.0 | 2.835000 | 103.959999 | 36.670197 |
| 98 | 30.0 | 33.0 | 3.118500 | 113.000000 | 36.235371 |
| 99 | 30.0 | 41.0 | 0.810000 | 10.735000 | 13.253086 |
| 99 | 30.0 | 41.0 | 1.620000 | 21.469999 | 13.253086 |
| 99 | 30.0 | 41.0 | 2.430000 | 32.205002 | 13.253087 |
| 99 | 30.0 | 41.0 | 3.240000 | 42.939999 | 13.253086 |
| 99 | 30.0 | 41.0 | 4.050000 | 53.109997 | 13.113581 |
| 99 | 30.0 | 41.0 | 4.860000 | 63.844997 | 13.136830 |
| 99 | 30.0 | 41.0 | 5.670000 | 74.580002 | 13.153440 |
| 99 | 30.0 | 41.0 | 6.480000 | 84.750000 | 13.078704 |
| 99 | 30.0 | 41.0 | 7.289999 | 94.919998 | 13.020576 |
| 99 | 30.0 | 41.0 | 8.099999 | 103.959999 | 12.834569 |
| 100 | 30.0 | 50.9 | 2.025000 | 10.735000 | 5.301234 |
| 100 | 30.0 | 50.9 | 4.050000 | 21.469999 | 5.301234 |
| 100 | 30.0 | 50.9 | 6.075000 | 32.205002 | 5.301235 |
| 100 | 30.0 | 50.9 | 8.100000 | 43.504997 | 5.370987 |
| 100 | 30.0 | 50.9 | 10.125000 | 54.240002 | 5.357037 |
| 100 | 30.0 | 50.9 | 12.150001 | 64.974998 | 5.347736 |
| 100 | 30.0 | 50.9 | 14.174999 | 75.144997 | 5.301235 |
| 100 | 30.0 | 50.9 | 16.200001 | 85.879997 | 5.301234 |
| 100 | 30.0 | 50.9 | 18.224998 | 96.050003 | 5.270234 |
| 100 | 30.0 | 50.9 | 20.250000 | 105.655006 | 5.217531 |
| 101 | 30.0 | 65.8 | 6.750000 | 10.735000 | 1.590370 |
| 101 | 30.0 | 65.8 | 13.500001 | 22.035000 | 1.632222 |
| 101 | 30.0 | 65.8 | 20.250000 | 33.334999 | 1.646173 |
| 101 | 30.0 | 65.8 | 27.000002 | 45.200001 | 1.674074 |
| 101 | 30.0 | 65.8 | 33.750000 | 56.500000 | 1.674074 |
| 101 | 30.0 | 65.8 | 40.500000 | 67.800003 | 1.674074 |
| 101 | 30.0 | 65.8 | 47.249996 | 79.099998 | 1.674074 |
| 101 | 30.0 | 65.8 | 54.000004 | 89.834999 | 1.663611 |
| 101 | 30.0 | 65.8 | 60.749996 | 100.570000 | 1.655473 |
| 101 | 30.0 | 65.8 | 67.500000 | 110.740005 | 1.640593 |
| 102 | 30.0 | 75.2 | 13.500001 | 11.300000 | 0.837037 |
| 102 | 30.0 | 75.2 | 27.000002 | 22.600000 | 0.837037 |
| 102 | 30.0 | 75.2 | 40.500000 | 33.900002 | 0.837037 |
| 102 | 30.0 | 75.2 | 54.000004 | 45.200001 | 0.837037 |
| 102 | 30.0 | 75.2 | 67.500000 | 56.500000 | 0.837037 |
| 102 | 30.0 | 75.2 | 81.000000 | 67.800003 | 0.837037 |
| 102 | 30.0 | 75.2 | 94.499992 | 79.099998 | 0.837037 |
| 102 | 30.0 | 75.2 | 108.000008 | 90.400002 | 0.837037 |
| 102 | 30.0 | 75.2 | 121.499992 | 101.699997 | 0.837037 |
| 102 | 30.0 | 75.2 | 135.000000 | 111.870003 | 0.828667 |
| [illegible] | 30.0 | 88.6 | 15.750001 | 8.475000 | 0.538095 |

| | | | | | |
|---|---|---|---|---|---|
| 103 | 30.0 | 88.6 | 31.500002 | 16.950001 | 0.538095 |
| 103 | 30.0 | 88.6 | 47.250000 | 25.990000 | 0.550053 |
| 103 | 30.0 | 88.6 | 63.000004 | 35.030003 | 0.556032 |
| 103 | 30.0 | 88.6 | 78.750000 | 44.070000 | 0.559619 |
| 103 | 30.0 | 88.6 | 94.500000 | 52.544998 | 0.556032 |
| 103 | 30.0 | 88.6 | 110.249992 | 61.585003 | 0.558594 |
| 103 | 30.0 | 88.6 | 126.000008 | 70.625000 | 0.560516 |
| 103 | 30.0 | 88.6 | 141.749985 | 79.665001 | 0.562011 |
| 103 | 30.0 | 88.6 | 157.500000 | 88.139999 | 0.559619 |
| 104 | 30.0 | 96.9 | 20.250000 | 8.475000 | 0.418519 |
| 104 | 30.0 | 96.9 | 40.500000 | 15.820000 | 0.390617 |
| 104 | 30.0 | 96.9 | 60.750000 | 24.295000 | 0.399918 |
| 104 | 30.0 | 96.9 | 81.000000 | 32.205002 | 0.397593 |
| 104 | 30.0 | 96.9 | 101.250000 | 40.114998 | 0.396197 |
| 104 | 30.0 | 96.9 | 121.500000 | 48.025002 | 0.395268 |
| 104 | 30.0 | 96.9 | 141.750000 | 56.500000 | 0.398589 |
| 104 | 30.0 | 96.9 | 162.000000 | 64.974998 | 0.401080 |
| 104 | 30.0 | 96.9 | 182.249985 | 72.884995 | 0.399918 |
| 104 | 30.0 | 96.9 | 202.500000 | 80.229996 | 0.396197 |
| 105 | 30.0 | 109.2 | 29.250002 | 6.780000 | 0.231795 |
| 105 | 30.0 | 109.2 | 58.500004 | 12.995000 | 0.222137 |
| 105 | 30.0 | 109.2 | 87.750000 | 19.775000 | 0.225356 |
| 105 | 30.0 | 109.2 | 117.000008 | 26.554998 | 0.226966 |
| 105 | 30.0 | 109.2 | 131.624985 | 29.944998 | 0.227502 |
| 105 | 30.0 | 109.2 | 146.250000 | 33.334999 | 0.227932 |
| 105 | 30.0 | 109.2 | 175.500000 | 41.245003 | 0.235014 |
| 105 | 30.0 | 109.2 | 204.749985 | 46.895000 | 0.229035 |
| 105 | 30.0 | 109.2 | 234.000015 | 53.675003 | 0.229380 |
| 105 | 30.0 | 109.2 | 248.625000 | 56.500000 | 0.227250 |
| 106 | 30.0 | 120.9 | 27.000002 | 5.876000 | 0.217630 |
| 106 | 30.0 | 120.9 | 54.000004 | 10.396000 | 0.192519 |
| 106 | 30.0 | 120.9 | 81.000000 | 14.464000 | 0.178568 |
| 106 | 30.0 | 120.9 | 108.000008 | 19.436001 | 0.179963 |
| 106 | 30.0 | 120.9 | 135.000000 | 23.955999 | 0.177452 |
| 106 | 30.0 | 120.9 | 162.000000 | 28.927999 | 0.178568 |
| 106 | 30.0 | 120.9 | 188.999985 | 33.900002 | 0.179365 |
| 106 | 30.0 | 120.9 | 216.000015 | 38.872002 | 0.179963 |
| 106 | 30.0 | 120.9 | 242.999985 | 43.843998 | 0.180428 |
| 106 | 30.0 | 120.9 | 270.000000 | 48.816006 | 0.180800 |
| 107 | 30.0 | 129.8 | 27.000002 | 3.672500 | 0.136018 |
| 107 | 30.0 | 129.8 | 54.000004 | 7.062500 | 0.130787 |
| 107 | 30.0 | 129.8 | 81.000000 | 10.735000 | 0.132531 |
| 107 | 30.0 | 129.8 | 108.000008 | 14.407499 | 0.133403 |
| 107 | 30.0 | 129.8 | 135.000000 | 18.362499 | 0.136019 |
| 107 | 30.0 | 129.8 | 162.000000 | 22.317501 | 0.137762 |
| 107 | 30.0 | 129.8 | 188.999985 | 26.272499 | 0.139008 |
| 107 | 30.0 | 129.8 | 216.000015 | 30.227501 | 0.139942 |
| 107 | 30.0 | 129.8 | 242.999985 | 34.465000 | 0.141831 |
| 107 | 30.0 | 129.8 | 270.000000 | 38.137501 | 0.141250 |
| 108 | 30.0 | 141.0 | 27.000002 | 3.051000 | 0.113000 |
| 108 | 30.0 | 141.0 | 54.000004 | 5.763000 | 0.106722 |
| 108 | 30.0 | 141.0 | 81.000000 | 8.475000 | 0.104630 |
| 108 | 30.0 | 141.0 | 108.000008 | 11.356500 | 0.105153 |
| 108 | 30.0 | 141.0 | 135.000000 | 14.238000 | 0.105467 |
| 108 | 30.0 | 141.0 | 162.000000 | 17.289000 | 0.106722 |
| 108 | 30.0 | 141.0 | 188.999985 | 20.170502 | 0.106722 |
| 108 | 30.0 | 141.0 | 216.000015 | 23.221500 | 0.107507 |
| 108 | 30.0 | 141.0 | 242.999985 | 26.272499 | 0.108117 |
| 108 | 30.0 | 141.0 | 270.000000 | 29.154001 | 0.107978 |

50% w/w COAL-BITUMEN - HEATING

| | | | | | |
|---|---|---|---|---|---|
| 113 | 50.0 | 47.5 | 0.135000 | 12.429999 | 92.074066 |
| 113 | 50.0 | 47.5 | 0.270000 | 23.164999 | 85.796288 |
| 113 | 50.0 | 47.5 | 0.405000 | 32.770000 | 80.913574 |
| 113 | 50.0 | 47.5 | 0.540000 | 41.245003 | 76.379631 |
| 113 | 50.0 | 47.5 | 0.675000 | 49.154999 | 72.822220 |
| 113 | 50.0 | 47.5 | 0.810000 | 58.759998 | 72.543205 |
| 113 | 50.0 | 47.5 | 0.945000 | 66.669998 | 70.550262 |
| 113 | 50.0 | 47.5 | 1.080000 | 75.144997 | 69.578697 |
| 113 | 50.0 | 47.5 | 1.215000 | 81.925003 | 67.427994 |
| 113 | 50.0 | 47.5 | 1.350000 | 89.270004 | 66.125931 |
| 114 | 50.0 | 56.0 | 0.405000 | 16.950001 | 41.851852 |
| 114 | 50.0 | 56.0 | 0.810000 | 24.859999 | 30.691357 |
| 114 | 50.0 | 56.0 | 1.215000 | 36.160000 | 29.761316 |
| 114 | 50.0 | 56.0 | 1.620000 | 46.329998 | 28.598764 |
| 114 | 50.0 | 56.0 | 2.025000 | 57.064999 | 28.180248 |
| 114 | 50.0 | 56.0 | 2.430000 | 67.235008 | 27.668726 |
| 114 | 50.0 | 56.0 | 2.835000 | 77.404999 | 27.303352 |
| 114 | 50.0 | 56.0 | 3.240000 | 87.009995 | 26.854937 |
| 114 | 50.0 | 56.0 | 3.645000 | 96.050003 | 26.351170 |
| 114 | 50.0 | 56.0 | 4.050000 | 105.089996 | 25.948149 |
| 115 | 50.0 | 69.7 | 0.900000 | 12.995000 | 14.438889 |
| 115 | 50.0 | 69.7 | 1.800000 | 24.295000 | 13.497222 |
| 115 | 50.0 | 69.7 | 2.700000 | 35.595001 | 13.183333 |
| 115 | 50.0 | 69.7 | 3.600000 | 46.329998 | 12.869443 |
| 115 | 50.0 | 69.7 | 4.500000 | 57.064999 | 12.681110 |
| 115 | 50.0 | 69.7 | 5.400000 | 66.669998 | 12.346295 |
| 115 | 50.0 | 69.7 | 6.300000 | 76.275002 | 12.107143 |
| 115 | 50.0 | 69.7 | 7.200000 | 85.879997 | 11.927777 |
| 115 | 50.0 | 69.7 | 8.099999 | 94.919998 | 11.718519 |
| 115 | 50.0 | 69.7 | 9.000000 | 102.830002 | 11.425556 |
| 116 | 50.0 | 78.8 | 1.485000 | 13.560000 | 9.131313 |
| 116 | 50.0 | 78.8 | 2.970000 | 24.859999 | 8.370370 |
| 116 | 50.0 | 78.8 | 4.455000 | 36.724998 | 8.243546 |
| 116 | 50.0 | 78.8 | 5.940000 | 47.459999 | 7.989899 |
| 116 | 50.0 | 78.8 | 7.425000 | 57.629997 | 7.761616 |
| 116 | 50.0 | 78.8 | 8.910000 | 67.800003 | 7.609428 |
| 116 | 50.0 | 78.8 | 10.395000 | 76.840004 | 7.392016 |
| 116 | 50.0 | 78.8 | 11.880000 | 86.445000 | 7.276515 |
| 116 | 50.0 | 78.8 | 13.364999 | 95.485001 | 7.144408 |
| 116 | 50.0 | 78.8 | 14.849999 | 103.394997 | 6.962626 |
| 117 | 50.0 | 87.6 | 2.475000 | 13.560000 | 5.478788 |
| 117 | 50.0 | 87.6 | 4.950000 | 25.424999 | 5.136363 |
| 117 | 50.0 | 87.6 | 7.425000 | 36.724998 | 4.946127 |
| 117 | 50.0 | 87.6 | 9.900001 | 48.025002 | 4.851010 |
| 117 | 50.0 | 87.6 | 12.375000 | 58.195000 | 4.702626 |
| 117 | 50.0 | 87.6 | 14.850000 | 68.365005 | 4.603704 |
| 117 | 50.0 | 87.6 | 17.324999 | 77.970001 | 4.500433 |
| 117 | 50.0 | 87.6 | 19.800001 | 87.009995 | 4.394444 |
| 117 | 50.0 | 87.6 | 22.274998 | 97.745003 | 4.388104 |
| 117 | 50.0 | 87.6 | 24.750000 | 104.525009 | 4.223233 |
| 118 | 50.0 | 106.8 | 6.750000 | 12.995000 | 1.925185 |
| 118 | 50.0 | 106.8 | 13.500001 | 23.730000 | 1.757778 |
| 118 | 50.0 | 106.8 | 20.250000 | 34.465000 | 1.701975 |
| 118 | 50.0 | 106.8 | 27.000002 | 45.200001 | 1.674074 |
| 118 | 50.0 | 106.8 | 33.750000 | 55.370003 | 1.640593 |
| 118 | 50.0 | 106.8 | 40.500000 | 65.540001 | 1.618272 |
| 118 | 50.0 | 106.8 | 47.249996 | 75.144997 | 1.590370 |
| 118 | 50.0 | 106.8 | 54.000004 | 84.750000 | 1.569444 |
| 118 | 50.0 | 106.8 | 60.749996 | 94.354996 | 1.553169 |
| 118 | 50.0 | 106.8 | 67.500000 | 103.394997 | 1.531778 |
| 119 | 50.0 | 118.4 | 8.100000 | 13.560000 | 1.674074 |

| | | | | | |
|---|---|---|---|---|---|
| 119 | 50.0 | 118.4 | 16.200001 | 25.424999 | 1.569444 |
| 119 | 50.0 | 118.4 | 24.300001 | 36.160000 | 1.488066 |
| 119 | 50.0 | 118.4 | 32.400002 | 47.459999 | 1.464815 |
| 119 | 50.0 | 118.4 | 40.500000 | 57.629997 | 1.422963 |
| 119 | 50.0 | 118.4 | 48.600002 | 67.235008 | 1.383436 |
| 119 | 50.0 | 118.4 | 56.699997 | 76.840004 | 1.355203 |
| 119 | 50.0 | 118.4 | 64.800003 | 86.445000 | 1.334028 |
| 119 | 50.0 | 118.4 | 72.899994 | 96.050003 | 1.317558 |
| 119 | 50.0 | 118.4 | 81.000000 | 103.959999 | 1.283457 |
| 120 | 50.0 | 128.0 | 10.350000 | 12.429999 | 1.200966 |
| 120 | 50.0 | 128.0 | 20.700001 | 23.730000 | 1.146377 |
| 120 | 50.0 | 128.0 | 31.050001 | 35.030003 | 1.128180 |
| 120 | 50.0 | 128.0 | 41.400002 | 45.200001 | 1.091787 |
| 120 | 50.0 | 128.0 | 46.574997 | 49.719997 | 1.067526 |
| 120 | 50.0 | 128.0 | 51.750000 | 54.805000 | 1.059034 |
| 120 | 50.0 | 128.0 | 56.925003 | 59.889996 | 1.052086 |
| 120 | 50.0 | 128.0 | 62.100002 | 65.540001 | 1.055395 |
| 120 | 50.0 | 128.0 | 72.449997 | 74.580002 | 1.029400 |
| 120 | 50.0 | 128.0 | 82.800003 | 84.184998 | 1.016727 |
| 121 | 50.0 | 138.0 | 13.500001 | 12.429999 | 0.920741 |
| 121 | 50.0 | 138.0 | 27.000002 | 23.730000 | 0.878889 |
| 121 | 50.0 | 138.0 | 33.750000 | 29.944998 | 0.887259 |
| 121 | 50.0 | 138.0 | 40.500000 | 35.030003 | 0.864938 |
| 121 | 50.0 | 138.0 | 54.000004 | 45.764999 | 0.847500 |
| 121 | 50.0 | 138.0 | 67.500000 | 56.500000 | 0.837037 |
| 121 | 50.0 | 138.0 | 81.000000 | 65.540001 | 0.809136 |
| 121 | 50.0 | 138.0 | 94.499992 | 76.275002 | 0.807143 |
| 121 | 50.0 | 138.0 | 121.499992 | 96.615005 | 0.795185 |
| 121 | 50.0 | 138.0 | 135.000000 | 104.525009 | 0.774259 |
| 122 | 50.0 | 147.0 | 18.000000 | 13.560000 | 0.753333 |
| 122 | 50.0 | 147.0 | 36.000000 | 25.424999 | 0.706250 |
| 122 | 50.0 | 147.0 | 54.000000 | 36.724998 | 0.680093 |
| 122 | 50.0 | 147.0 | 72.000000 | 48.025002 | 0.667014 |
| 122 | 50.0 | 147.0 | 90.000000 | 58.759998 | 0.652889 |
| 122 | 50.0 | 147.0 | 108.000000 | 69.494995 | 0.643472 |
| 122 | 50.0 | 147.0 | 125.999992 | 79.665001 | 0.632262 |
| 122 | 50.0 | 147.0 | 144.000000 | 90.400002 | 0.627778 |
| 122 | 50.0 | 147.0 | 161.999985 | 101.134995 | 0.624290 |
| 122 | 50.0 | 147.0 | 180.000000 | 110.740005 | 0.615222 |

BITUMEN - COOLING

| | | | | | |
|---|---|---|---|---|---|
| 75 | 0.0 | 131.8 | 27.000002 | 1.243000 | 0.046037 |
| 75 | 0.0 | 131.8 | 54.000004 | 2.373000 | 0.043944 |
| 75 | 0.0 | 131.8 | 81.000000 | 3.616000 | 0.044642 |
| 75 | 0.0 | 131.8 | 108.000008 | 4.859000 | 0.044991 |
| 75 | 0.0 | 131.8 | 135.000000 | 5.989000 | 0.044363 |
| 75 | 0.0 | 131.8 | 162.000000 | 7.345000 | 0.045340 |
| 75 | 0.0 | 131.8 | 188.999985 | 8.588000 | 0.045439 |
| 75 | 0.0 | 131.8 | 216.000015 | 9.831000 | 0.045514 |
| 75 | 0.0 | 131.8 | 242.999985 | 11.187000 | 0.046037 |
| 75 | 0.0 | 131.8 | 270.000000 | 12.543000 | 0.046456 |
| 76 | 0.0 | 114.5 | 27.000002 | 2.542500 | 0.094167 |
| 76 | 0.0 | 114.5 | 54.000004 | 5.085000 | 0.094167 |
| 76 | 0.0 | 114.5 | 81.000000 | 7.458000 | 0.092074 |
| 76 | 0.0 | 114.5 | 108.000008 | 10.000499 | 0.092597 |
| 76 | 0.0 | 114.5 | 135.000000 | 12.543000 | 0.092911 |
| 76 | 0.0 | 114.5 | 162.000000 | 15.085500 | 0.093120 |
| 76 | 0.0 | 114.5 | 188.999985 | 17.628000 | 0.093270 |
| 76 | 0.0 | 114.5 | 216.000015 | 20.170502 | 0.093382 |
| 76 | 0.0 | 114.5 | 242.999985 | 22.712999 | 0.093469 |
| 76 | 0.0 | 114.5 | 270.000000 | 25.425001 | 0.094167 |
| 77 | 0.0 | 93.8 | 27.000002 | 6.780000 | 0.251111 |
| 77 | 0.0 | 93.8 | 54.000004 | 13.559999 | 0.251111 |
| 77 | 0.0 | 93.8 | 81.000000 | 20.000998 | 0.246926 |
| 77 | 0.0 | 93.8 | 108.000008 | 26.781000 | 0.247972 |
| 77 | 0.0 | 93.8 | 135.000000 | 33.561001 | 0.248600 |
| 77 | 0.0 | 93.8 | 162.000000 | 40.341003 | 0.249019 |
| 77 | 0.0 | 93.8 | 188.999985 | 47.120998 | 0.249317 |
| 77 | 0.0 | 93.8 | 216.000015 | 53.901001 | 0.249542 |
| 77 | 0.0 | 93.8 | 242.999985 | 60.341999 | 0.248321 |
| 77 | 0.0 | 93.8 | 270.000000 | 67.122002 | 0.248600 |
| 78 | 0.0 | 73.4 | 11.250000 | 9.040000 | 0.803556 |
| 78 | 0.0 | 73.4 | 22.500000 | 18.080000 | 0.803556 |
| 78 | 0.0 | 73.4 | 33.750000 | 27.685001 | 0.820296 |
| 78 | 0.0 | 73.4 | 45.000000 | 36.724998 | 0.816111 |
| 78 | 0.0 | 73.4 | 56.250000 | 45.764999 | 0.813600 |
| 78 | 0.0 | 73.4 | 67.500000 | 55.370003 | 0.820296 |
| 78 | 0.0 | 73.4 | 78.750000 | 64.410004 | 0.817905 |
| 78 | 0.0 | 73.4 | 90.000000 | 73.449997 | 0.816111 |
| 78 | 0.0 | 73.4 | 101.249992 | 83.055000 | 0.820296 |
| 78 | 0.0 | 73.4 | 112.500000 | 91.529999 | 0.813600 |
| 79 | 0.0 | 53.9 | 2.250000 | 9.040000 | 4.017778 |
| 79 | 0.0 | 53.9 | 4.500000 | 18.080000 | 4.017778 |
| 79 | 0.0 | 53.9 | 6.750000 | 27.120001 | 4.017778 |
| 79 | 0.0 | 53.9 | 9.000000 | 36.160000 | 4.017778 |
| 79 | 0.0 | 53.9 | 11.250000 | 45.200001 | 4.017778 |
| 79 | 0.0 | 53.9 | 13.500000 | 54.240002 | 4.017778 |
| 79 | 0.0 | 53.9 | 15.749999 | 63.279999 | 4.017778 |
| 79 | 0.0 | 53.9 | 18.000000 | 72.320000 | 4.017778 |
| 79 | 0.0 | 53.9 | 20.249998 | 81.360001 | 4.017778 |
| 79 | 0.0 | 53.9 | 22.500000 | 89.270004 | 3.967556 |

10% w/w COAL-BITUMEN - COOLING

| | | | | | |
|---|---|---|---|---|---|
| 92 | 10.0 | 125.6 | 22.500000 | 2.373000 | 0.105467 |
| 92 | 10.0 | 125.6 | 45.000000 | 4.746000 | 0.105467 |
| 92 | 10.0 | 125.6 | 67.500000 | 7.119000 | 0.105467 |
| 92 | 10.0 | 125.6 | 90.000000 | 9.492000 | 0.105467 |
| 92 | 10.0 | 125.6 | 112.500000 | 11.865000 | 0.105467 |
| 92 | 10.0 | 125.6 | 135.000000 | 14.238000 | 0.105467 |
| 92 | 10.0 | 125.6 | 157.500000 | 16.441500 | 0.104390 |
| 92 | 10.0 | 125.6 | 180.000000 | 18.814501 | 0.104525 |
| 92 | 10.0 | 125.6 | 202.499985 | 21.187500 | 0.104630 |
| 92 | 10.0 | 125.6 | 225.000000 | 23.730000 | 0.105467 |
| 93 | 10.0 | 97.3 | 20.250000 | 9.605000 | 0.474321 |
| 93 | 10.0 | 97.3 | 40.500000 | 19.775000 | 0.488272 |
| 93 | 10.0 | 97.3 | 60.750000 | 29.944998 | 0.492922 |
| 93 | 10.0 | 97.3 | 81.000000 | 40.114998 | 0.495247 |
| 93 | 10.0 | 97.3 | 101.250000 | 50.285000 | 0.496642 |
| 93 | 10.0 | 97.3 | 121.500000 | 61.020004 | 0.502222 |
| 93 | 10.0 | 97.3 | 141.750000 | 71.190002 | 0.502222 |
| 93 | 10.0 | 97.3 | 162.000000 | 81.360001 | 0.502222 |
| 93 | 10.0 | 97.3 | 182.249985 | 91.529999 | 0.502222 |
| 93 | 10.0 | 97.3 | 202.500000 | 101.699997 | 0.502222 |
| 94 | 10.0 | 79.4 | 6.750000 | 11.300000 | 1.674074 |
| 94 | 10.0 | 79.4 | 13.500001 | 22.035000 | 1.632222 |
| 94 | 10.0 | 79.4 | 20.250000 | 32.770000 | 1.618272 |
| 94 | 10.0 | 79.4 | 27.000002 | 44.070000 | 1.632222 |
| 94 | 10.0 | 79.4 | 33.750000 | 55.370003 | 1.640593 |
| 94 | 10.0 | 79.4 | 40.500000 | 66.669998 | 1.646173 |
| 94 | 10.0 | 79.4 | 47.249996 | 77.404999 | 1.638201 |
| 94 | 10.0 | 79.4 | 54.000004 | 88.139999 | 1.632222 |
| 94 | 10.0 | 79.4 | 60.749996 | 98.875000 | 1.627572 |
| 94 | 10.0 | 79.4 | 67.500000 | 109.044991 | 1.615481 |
| 95 | 10.0 | 56.1 | 1.125000 | 10.170000 | 9.040000 |
| 95 | 10.0 | 56.1 | 2.250000 | 20.340000 | 9.040000 |
| 95 | 10.0 | 56.1 | 3.375000 | 30.510002 | 9.040001 |
| 95 | 10.0 | 56.1 | 4.500000 | 40.680000 | 9.040000 |
| 95 | 10.0 | 56.1 | 5.625000 | 50.849998 | 9.040000 |
| 95 | 10.0 | 56.1 | 6.750000 | 60.455002 | 8.956297 |
| 95 | 10.0 | 56.1 | 7.875000 | 70.060005 | 8.896509 |
| 95 | 10.0 | 56.1 | 9.000000 | 79.665001 | 8.851666 |
| 95 | 10.0 | 56.1 | 10.124999 | 89.834999 | 8.872593 |
| 95 | 10.0 | 56.1 | 11.250000 | 98.875000 | 8.788889 |
| 96 | 10.0 | 32.7 | 0.180000 | 14.690000 | 81.611107 |
| 96 | 10.0 | 32.7 | 0.360000 | 28.250000 | 78.472221 |
| 96 | 10.0 | 32.7 | 0.540000 | 42.939999 | 79.518517 |
| 96 | 10.0 | 32.7 | 0.720000 | 56.500000 | 78.472221 |
| 96 | 10.0 | 32.7 | 0.810000 | 64.410004 | 79.518532 |
| 96 | 10.0 | 32.7 | 0.900000 | 71.190002 | 79.099998 |
| 96 | 10.0 | 32.7 | 1.080000 | 86.445000 | 80.041664 |
| 96 | 10.0 | 32.7 | 1.170000 | 92.659996 | 79.196579 |
| 96 | 10.0 | 32.7 | 1.260000 | 98.875000 | 78.472221 |
| 96 | 10.0 | 32.7 | 1.440000 | 113.000000 | 78.472221 |

30% w/w COAL-BITUMEN - COOLING

| | | | | | |
|---|---|---|---|---|---|
| 109 | 30.0 | 115.4 | 27.000002 | 8.475000 | 0.313889 |
| 109 | 30.0 | 115.4 | 54.000004 | 16.950001 | 0.313889 |
| 109 | 30.0 | 115.4 | 81.000000 | 25.424999 | 0.313889 |
| 109 | 30.0 | 115.4 | 108.000008 | 34.465000 | 0.319120 |
| 109 | 30.0 | 115.4 | 135.000000 | 42.939999 | 0.318074 |
| 109 | 30.0 | 115.4 | 162.000000 | 51.415001 | 0.317377 |
| 109 | 30.0 | 115.4 | 188.999985 | 59.889996 | 0.316878 |
| 109 | 30.0 | 115.4 | 216.000015 | 68.365005 | 0.316505 |
| 109 | 30.0 | 115.4 | 242.999985 | 77.404999 | 0.318539 |
| 109 | 30.0 | 115.4 | 270.000000 | 85.879997 | 0.318074 |
| 110 | 30.0 | 96.2 | 9.000000 | 9.040000 | 1.004444 |
| 110 | 30.0 | 96.2 | 18.000000 | 18.080000 | 1.004444 |
| 110 | 30.0 | 96.2 | 27.000000 | 27.685001 | 1.025370 |
| 110 | 30.0 | 96.2 | 36.000000 | 36.724998 | 1.020139 |
| 110 | 30.0 | 96.2 | 45.000000 | 45.764999 | 1.017000 |
| 110 | 30.0 | 96.2 | 54.000000 | 54.805000 | 1.014907 |
| 110 | 30.0 | 96.2 | 62.999996 | 63.844997 | 1.013413 |
| 110 | 30.0 | 96.2 | 72.000000 | 71.754997 | 0.996597 |
| 110 | 30.0 | 96.2 | 80.999992 | 80.794998 | 0.997469 |
| 110 | 30.0 | 96.2 | 90.000000 | 89.270004 | 0.991889 |
| 111 | 30.0 | 73.0 | 1.800000 | 9.040000 | 5.022222 |
| 111 | 30.0 | 73.0 | 3.600000 | 18.645000 | 5.179167 |
| 111 | 30.0 | 73.0 | 5.400000 | 27.685001 | 5.126852 |
| 111 | 30.0 | 73.0 | 7.200000 | 37.290001 | 5.179167 |
| 111 | 30.0 | 73.0 | 9.000000 | 46.329998 | 5.147778 |
| 111 | 30.0 | 73.0 | 10.800000 | 55.370003 | 5.126852 |
| 111 | 30.0 | 73.0 | 12.599999 | 64.410004 | 5.111905 |
| 111 | 30.0 | 73.0 | 14.400001 | 73.449997 | 5.100694 |
| 111 | 30.0 | 73.0 | 16.199999 | 82.490005 | 5.091976 |
| 111 | 30.0 | 73.0 | 18.000000 | 90.965004 | 5.053611 |
| 112 | 30.0 | 49.0 | 0.180000 | 9.605000 | 53.361111 |
| 112 | 30.0 | 49.0 | 0.360000 | 19.775000 | 54.930553 |
| 112 | 30.0 | 49.0 | 0.540000 | 28.814999 | 53.361107 |
| 112 | 30.0 | 49.0 | 0.720000 | 38.420002 | 53.361111 |
| 112 | 30.0 | 49.0 | 0.900000 | 47.459999 | 52.733330 |
| 112 | 30.0 | 49.0 | 1.080000 | 57.064999 | 52.837959 |
| 112 | 30.0 | 49.0 | 1.260000 | 65.540001 | 52.015873 |
| 112 | 30.0 | 49.0 | 1.440000 | 75.144997 | 52.184025 |
| 112 | 30.0 | 49.0 | 1.620000 | 84.184998 | 51.966053 |
| 112 | 30.0 | 49.0 | 1.800000 | 92.659996 | 51.477772 |

50% w/w COAL-BITUMEN - COOLING

| | | | | | |
|---|---|---|---|---|---|
| 123 | 50.0 | 127.2 | 6.750000 | 13.560000 | 2.008889 |
| 123 | 50.0 | 127.2 | 13.500001 | 25.424999 | 1.883333 |
| 123 | 50.0 | 127.2 | 20.250000 | 36.724998 | 1.813580 |
| 123 | 50.0 | 127.2 | 27.000002 | 47.459999 | 1.757778 |
| 123 | 50.0 | 127.2 | 33.750000 | 57.629997 | 1.707556 |
| 123 | 50.0 | 127.2 | 40.500000 | 67.800003 | 1.674074 |
| 123 | 50.0 | 127.2 | 47.249996 | 77.404999 | 1.638201 |
| 123 | 50.0 | 127.2 | 54.000004 | 87.009995 | 1.611296 |
| 123 | 50.0 | 127.2 | 60.749996 | 96.050003 | 1.581070 |
| 123 | 50.0 | 127.2 | 67.500000 | 104.525009 | 1.548519 |
| 124 | 50.0 | 108.0 | 2.250000 | 12.429999 | 5.524444 |
| 124 | 50.0 | 108.0 | 4.500000 | 23.164999 | 5.147778 |
| 124 | 50.0 | 108.0 | 6.750000 | 33.900002 | 5.022223 |
| 124 | 50.0 | 108.0 | 9.000000 | 43.504997 | 4.833889 |
| 124 | 50.0 | 108.0 | 11.250000 | 53.109997 | 4.720889 |
| 124 | 50.0 | 108.0 | 13.500000 | 62.150002 | 4.603704 |
| 124 | 50.0 | 108.0 | 15.749999 | 71.190002 | 4.520000 |
| 124 | 50.0 | 108.0 | 18.000000 | 80.229996 | 4.457222 |
| 124 | 50.0 | 108.0 | 20.249998 | 88.139999 | 4.352593 |
| 124 | 50.0 | 108.0 | 22.500000 | 96.050003 | 4.268889 |
| 125 | 50.0 | 88.5 | 1.125000 | 15.255001 | 13.560001 |
| 125 | 50.0 | 88.5 | 2.250000 | 27.685001 | 12.304445 |
| 125 | 50.0 | 88.5 | 3.375000 | 40.680000 | 12.053333 |
| 125 | 50.0 | 88.5 | 4.500000 | 51.980000 | 11.551111 |
| 125 | 50.0 | 88.5 | 5.625000 | 64.410004 | 11.450667 |
| 125 | 50.0 | 88.5 | 6.750000 | 74.580002 | 11.048889 |
| 125 | 50.0 | 88.5 | 7.875000 | 85.879997 | 10.905397 |
| 125 | 50.0 | 88.5 | 9.000000 | 96.050003 | 10.672222 |
| 125 | 50.0 | 88.5 | 10.124999 | 106.219994 | 10.490865 |
| 125 | 50.0 | 88.5 | 10.912500 | 113.000000 | 10.355097 |
| 126 | 50.0 | 68.5 | 0.180000 | 12.995000 | 72.194443 |
| 126 | 50.0 | 68.5 | 0.360000 | 25.424999 | 70.624992 |
| 126 | 50.0 | 68.5 | 0.540000 | 37.290001 | 69.055557 |
| 126 | 50.0 | 68.5 | 0.720000 | 47.459999 | 65.916664 |
| 126 | 50.0 | 68.5 | 0.900000 | 57.629997 | 64.033325 |
| 126 | 50.0 | 68.5 | 1.080000 | 67.800003 | 62.777779 |
| 126 | 50.0 | 68.5 | 1.260000 | 76.840004 | 60.984131 |
| 126 | 50.0 | 68.5 | 1.440000 | 86.445000 | 60.031246 |
| 126 | 50.0 | 68.5 | 1.620000 | 95.485001 | 58.941364 |
| 126 | 50.0 | 68.5 | 1.800000 | 103.959999 | 57.755554 |